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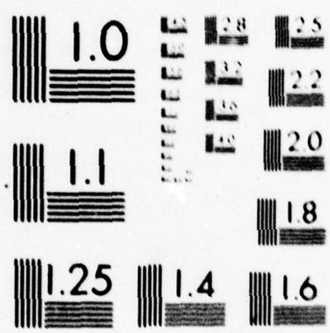

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FINAL REPORT

Integrated AUTODIN System (IAS)

MID-TERM ARCHITECTURE DEFINITION

DCA100–77–C–0057

Task 1-78/1/6

February 20, 1979

Communications and Information Technology Division

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of the IAS Architecture definition process for the mid-term (1984-88). The mid-term definition process was directed toward the definition of an overall top-down system architecture and the definition of new system elements required to support this architecture.

EXECUTIVE SUMMARY

Commencing with its appointment by OSD/DTACCS (now ASD/C^3I) in early 1975 as the AUTODIN System Manager, the Defense Communications Agency (DCA) has had responsibility for development of an Integrated AUTODIN System Architecture (IASA). The purpose of the IASA is to guide the evolution of the Defense Communications System's AUTODIN subsystem towards a more secure, accurate, survivable, and efficient means of message processing and data communications while offering standard solutions to user requirements. The IASA is organized into three architectural descriptions corresponding to the three major time periods in the evolutionary development of an Integrated AUTODIN System:

- Near-Term (1978-1983) - initial implementation of the AUTODIN II packet switched data network and consolidation with the existing AUTODIN I narrative/record message switched network

- Mid-Term (1984-1988) - expansion of the AUTODIN II data service worldwide, closure of AUTODIN I ASCs, introduction of standardized terminals, full integration of AUTODIN I and II

- Far-Term (Post 1988) - complete integration, narrative/record and data service worldwide, continued evolution toward the third generation DCS.

Presented in this report are the results of the IAS Architecture definition process applicable to the Mid-Term. Previous effort in this process was directed toward identification and analysis of implementation alternatives for the Near-Term (1978-1983). The Near-Term work, described in the IAS Architecture Report of December, 1977, was intended to shape decisions on the implementation and/or use of existing and readily available hardware/software components in order to achieve a Near-Term capability. The Mid-Term architecture analyses, by contrast, were directed toward the development of an overall, top-down system architecture, and the definition of new system elements required to support this architecture.

Presented herein are the preferred architecture for the Mid-Term, two alternate architectures and a description of the process and rationale for selecting the preferred architecture. In addition, a proposed transition approach to achieve the preferred architecture and to identify the actions required to evolve from the Near-Term IAS Architecture of 1983 to the Mid-Term IAS architecture of 1988 is described. In addition, this report includes guidance in planning and programming for a new family of terminals, and other hardware/software components of the IAS.

Based on ASD(C^3I) guidance and overall AUTODIN system requirements, the major architectural objectives relevant to the Mid-Term are:

- Expand AUTODIN II to provide a worldwide data backbone
- Complete phase-out of AUTODIN I switches
- Standardize terminals/AMPEs
- Reallocate ASC functions to other IAS elements
- Enhance system survivability
- Enhance tactical and allied forces interoperability with DCS
- Accomplish the above objectives via evolution.

Consistent with these objectives, the IAS Architecture definition effort over the past year has been directed toward the following objectives:

- Define viable candidate architectures for the Mid-Term
- Recommend a preferred Mid-Term Architecture for the IAS
- Evaluate the differences between the preferred architecture and viable alternatives
- Define an approach to transition from the Near-Term IAS to the Mid-Term IAS.

The process of defining the Mid-Term Architecture for the IAS was constrained to consider only those architectural alternatives which are technically and economically feasible within the Mid-Term time frame, consistent with the objectives of the Integrated AUTODIN System Architecture, and finally, consistent with the evolutionary philosophy of the Integrated AUTODIN System. The principal constraints on the architecture definition process were the following:

- Current AUTODIN I inventory assets
- Current AUTODIN II development status
- Inter-Service/Agency Automated Message Processing Exchange (I-S/A AMPE) program status
- Available technology.

For the Near-Term, architecture definition was issue oriented and addressed specific options available to the system implementer. The architecture definition process in support of the Mid-Term, on the

other hand, is considerably broader in scope, and is aimed toward definition of a top-down, overall architectural description.

The approach to defining the Mid-Term IAS Architecture was based on the following three analysis efforts.

- Definition of Mid-Term requirements and operating environment
- Generation of candidate architectures and selection of alternative architectures from among viable candidates
- Evaluation of alternatives and selection of a preferred architecture.

The definition of Mid-Term requirements and operating environment involved the projection of IAS input traffic; the projection of AMPE and I-S/A AMPE populations; the identification and definition of required IAS services and functions; and the identification and definition of candidate Mid-Term network elements.

Candidate network elements for the Mid-Term IAS include those elements of the Near-Term IAS architecture that can be retained through the mid-term as well as new elements that could be developed in time for the mid-term. The candidate IAS elements and their characteristics are the following:

- Packet Switch Node (PSN). The PSNs installed in CONUS and overseas under the AUTODIN II program will be available in the mid-term time frame for use in the IAS backbone. Based on current traffic projections, the PSNs installed in the near-term should be sufficient to accommodate the total IAS busy hour traffic. The need for additional PSNs to be installed during the mid-term in order to support expansion into the far-term and/or growth in the network will be based upon user acceptance and experience with the initial operational network.
- Automated Message Processing Exchange (Near-Term I-S/A AMPE, AMME, LDMX/NAVCOMPARS, AF AMPE, Streamliner). Most of the MILDEP/Agency AMPE equipments will reach the end of their useful service life during the mid-term and will be replaced by standardized Inter-Service/Agency AMPEs. The MILDEP/Agency AMPEs are therefore, not considered principal network elements for the Mid-Term IAS. (Those MILDEP/Agency unique AMPEs retained in the mid-term will be treated the same as other large, automated AUTODIN I terminals in the IAS).

- AUTODIN Switching Center (ASC). A principal objective of the Mid-Term IAS Architecture is the closure of the existing ASCs both in CONUS and overseas. Therefore, ASCs will be retained in the Mid-Term IAS Architecture only as required to facilitate smooth and orderly transition.

- Central Service Facility (CSF). The CSF is a postulated new centralized network service element that would perform necessary user support functions and/or network functions to accomplish message delivery and provide needed user services. The CSF is accessed via the backbone network and does not directly terminate subscriber equipments. The specific functional capability of the CSF is dependent upon the architectural alternative selected.

- Inter-Service/Agency AMPE (I-S/A AMPE). This new element is postulated as a standardized replacement for the existing MILDEP/Agency AMPEs. It would provide a complete set of agreed upon common Service/Agency AMPE functions and have provision for accommodating a limited number of user unique functions. The I-S/A AMPE will be modular in both hardware and software such that great flexibility will be available to the Services and Agencies in tailoring the I-S/A AMPE for each installation. The basic functional capability of the I-S/A AMPE is essentially independent of the architectural alternative selected.

- Enhanced Inter-Service/Agency AMPE (I-S/A AMPE(E)). This new element is postulated as a network service element that will be derived from installed I-S/A AMPEs through modular expansion of software (and if necessary hardware). The I-S/A AMPE would, therefore, include all of the functions of an I-S/A AMPE as described above, and replace a normal I-S/A AMPE in the network at selected locations. However, the enhanced I-S/A AMPEs in the network would also provide the additional network functions needed to allow phase-out of remaining ASCs and provide new network functions. The I-S/A AMPE(E), like the I-S/A AMPE, will be modular and thus provide the Services and Agencies great flexibility in tailoring the I-S/A AMPE(E) to meet site requirements. The full functional capability of the I-S/A AMPE(E) depends on the architecture alternative.

- Common Family of AUTODIN Terminals (CFT). A new family of terminal equipments is being defined by DCS as part of the IASA program. This common family will include a full range of terminals from simple teletypewriter to highly automated user terminals. The functional capabilities of

these terminals will be defined on the basis of user requirements and are independent of the architectural alternatives selected.

It should be noted that not all of the candidate architectural elements are utilized in all architectural alternatives. In, addition, the roles of some elements are dependent upon the architectural alternatives in which they are used.

The set of candidate architectures was generated through a sequential decision tree approach based on three major architectural decision levels:

- Selection of a network element set from among the available candidate elements
- Allocation of functions among the selected element set
- Consideration of specific configuration/connectivity options within the architecture (e.g., dual/single connection of nodal elements).

The candidate definition process resulted in the identification of 23 candidate architectures. Further analysis reduced this set to three final alternative architectures. All three alternatives utilize the packet switched node (PSN) as the principal backbone switching element and the Inter-Service/Agency AMPE (I-S/A AMPE) as the principal access area message processing and communications concentrator element. The basic characteristics and distinctive features of the three candidates are summarized below:

- Alternative I - This alternative represents a centralized architecture with little or no hierarchical structure in the access area. All network and user services in this alternative are provided from a relatively small number of service elements connected to the backbone and accessed via the network. These service elements are the Centralized Service Facilities (CSF)
- Alternative II - This alternative represents a distributed architecture in which user and network services are provided from a common access area element, the enhanced I-S/A AMPE (I-S/A AMPE(E)). This results in a very flexible structure in the access area with services accessed both directly and via the backbone network. In addition, this architecture provides the maximum degree of commonality among network elements.

- Alternative III - This alternative represents a hybrid architecture between the centralized structure of Alternative I and the distributed structure of Alternative II. In this architecture, some services are provided by a centralized backbone service element (the CSF), and the remaining services are provided by a distributed access area element (the I-S/A AMPE(E)).

Each of these architectures provides the required Mid-Term IAS services and functions, and is consistent with the constraints and anticipated operating environment of the Mid-Term.

In order to select a preferred Mid-Term IAS Architecture, the three alternative architectures were evaluated with respect to both technical and cost factors. This evaluation was based on a series of quantitative and qualitative technical analyses performed in support of the IAS architecture definition. The major evaluation criteria used in these analyses are the following:

- Operational effectiveness
- Flexibility
- Survivability/Availability/Supportability
- Transition
- Cost

Based upon the results of the evaluation process, the preferred architecture for the Mid-Term IAS is Alternative II. This alternative was determined to be preferred to each of the other alternatives in three of the five major evaluation criteria including the two technical criteria which are considered most important for the Mid-Term IAS - transition and survivability/availability/supportability. A principal characteristic of this architecture which led to its selection is the consolidation/integration of network and user motivated functions into a single service element based upon the currently planned I-S/A AMPE program. This consolidation/integration provides significant potential benefits in both cost and performance, and contributes materially to the ease of transition from Near-Term to the Mid-Term network architecture.

The preferred architecture for the Mid-Term IAS presented in this report meets all of the major objectives of the IAS program. In addition, the recommended transition approach will provide an orderly evolution from the current AUTODIN through the Near-Term into the Mid-Term and eventually into the Far-Term.

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SECTION I

INTRODUCTION

1. PURPOSE

The Integrated AUTODIN System (IAS) Architecture is organized into three architecture descriptions corresponding to the three major time periods in the evolutionary development of an Integrated AUTODIN System:

- o Near-Term (1978-1983) - initial implementation of the AUTODIN II packet switched data network and consolidation with the existing AUTODIN I narrative/record message switched network
- o Mid-Term (1984-1988) - expansion of the AUTODIN II data service worldwide, closure of AUTODIN I ASCs, introduction of standardized terminals, full integration of AUTODIN I and II
- o Far-Term (Post 1988) - complete integration, narrative/record and data service worldwide, continued evolution toward the third generation DCS.

The Integrated AUTODIN System Architecture Report of December, 1977 identified implementation alternatives and recommendations for the Near-Term (Reference a). This report presents the preferred architecture for the Mid-Term, identifies two alternative architectures and describes the process and rationale for selecting the preferred architecture. In addition, this report describes a proposed transition approach to achieve the preferred architecture and identifies the actions required to evolve from the Near-Term IAS Architecture of 1983 to the Mid-Term IAS Architecture of 1988. The purpose of the IASA is to guide the evolution of the Defense Communications System's AUTODIN subsystem towards a more secure, accurate, survivable, and efficient means of message processing and data communications while offering standard solutions to user requirements.

It should be noted that the IAS will neither be a new system to be superimposed on all other user systems in a duplicative way, nor will it exploit technological advances in the data processing industry when there is no well defined need to do so.

2. BACKGROUND

In July, 1974, the General Accounting Office (GAO) published a report that was critical of the Department of Defence (DoD) for (1) not having a single agency responsible for management of the entire AUTODIN subsystem to include AUTODIN terminals; (2) for a poor

telecommunications center consolidation record; and (3) for duplication of effort and proliferation of AMPE-type AUTODIN terminals by the Military Departments (MILDEPs) and DoD Agencies. The GAO recommended to the DoD that a single AUTODIN manager be appointed to resolve the problems as they surfaced.

In February, 1975, OSD/DTACCS (now ASD(C3I)) acted on the GAO recommendation by tasking the Defense Communications Agency (DCA) in coordination with Services/Agencies, to develop an Integrated AUTODIN System Architecture (IASA) on a terminal-to-terminal basis and, based on that architecture, to define a common family of AUTODIN terminal hardware and software.

On 12 December 1975, OSD/DTACCS approved the DCA IASA development plan which would address the various elements (e.g., PSNs, AMPEs, terminals, etc.) as a single integrated system with processing functions allocated to system components on the basis of how and where they can best be performed. As a result of this plan, DCA is responsible for accomplishing three objectives: (1) a system architecture on a terminal-to-terminal basis; (2) terminal specifications; and (3) related standards, formats, and procedures.

As an outgrowth of the OSD tasking, JCS Memorandum of Policy 165, titled: AUTODIN and Associated Message Processing Systems, was issued on 5 May 1976. MOP 165 established AUTODIN as the DoD common-user data communications system, directed maximum use of the system elements, identified criteria for interservice telecommunications center consolidation and automation, provided safeguards to prevent proliferation of non-standard terminal systems, and provided policy and guidance for use of new equipments using automation techniques through the AUTODIN.

3. ORGANIZATION

The IASA Project organization is shown in Figure 1. Control of the project is exercised through the AUTODIN Systems Integration Branch (Code 534), Headquarters DCA. Technical Support is provided by the Defense Communications Engineering Center (DCEC). Representatives of DCA, MILDEPs, National Security Agency (NSA), Defense Intelligence Agency (DIA), and Defense Logistics Agency (DLA) are formed into a Technical/Policy Panel which serves as the forum for discussion of IASA issues. In addition, there are three working groups, each chaired by DCA, with participation from MILDEPs and DoD Agencies.

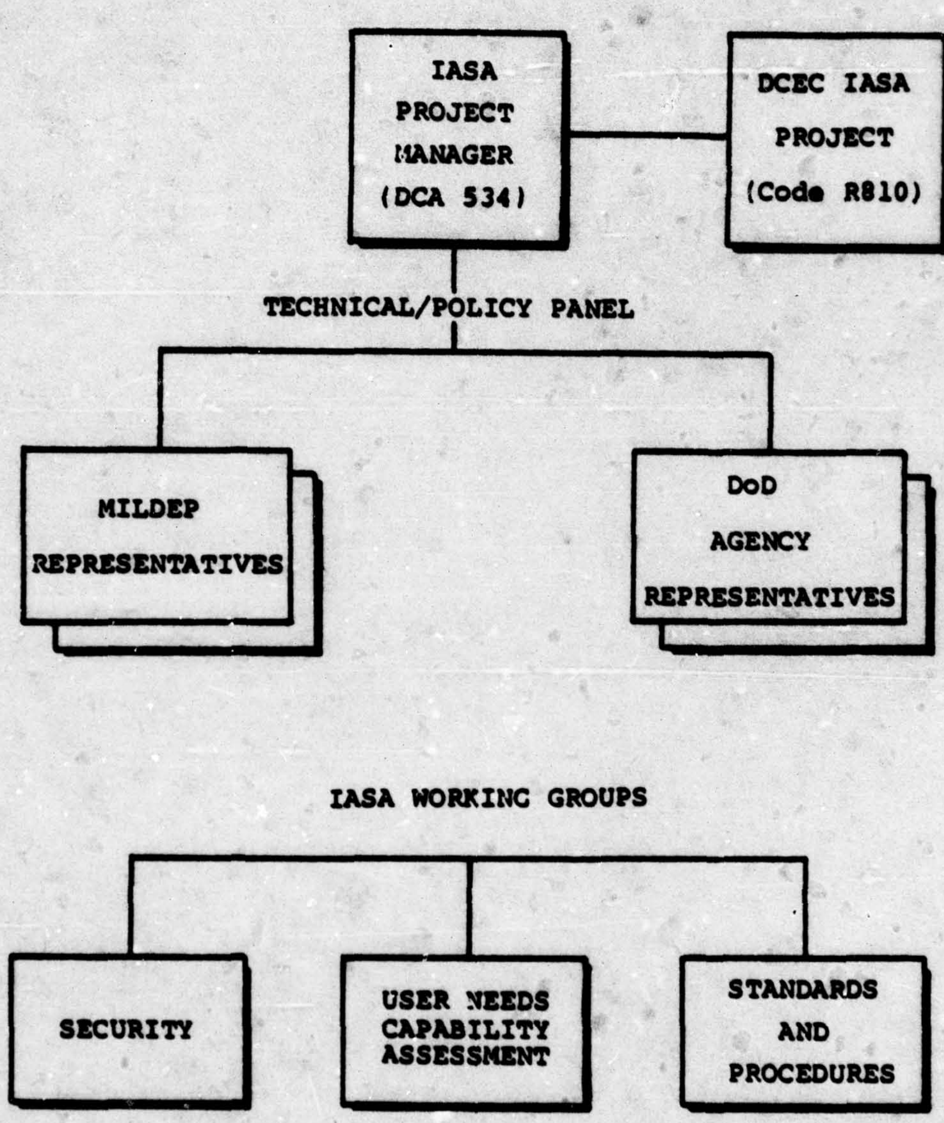


Figure 1. IASA Project Organization

4. IAS ARCHITECTURE OBJECTIVES

Based on ASD(C3I) guidance and overall AUTODIN system requirements, the major architectural objectives relevant to the mid-term are:

- Expand AUTODIN II to provide worldwide data backbone
- Complete phase-out of AUTODIN I switches
- Standardize terminals/AMPEs
- Reallocate ASC functions to other IAS elements
- Enhance system survivability
- Enhance tactical and allied forces interoperability with DCS
- Accomplish the above objectives via evolution.

Consistent with these objectives, the IAS Architecture definition effort over the past year has been directed toward the following objectives:

- Define viable candidate architectures for the mid-term
- Recommend a preferred Mid-Term Architecture for the IAS
- Evaluate the differences between the preferred architecture and viable alternatives
- Define an approach to transition from the Near-Term IAS to the Mid-Term IAS.

In addition, specific analyses were performed under this effort to address the following additional architectural objectives/issues:

- Project IAS user requirements through the mid-term
- Define the role of the Inter-Service/Agency AMPE
- Define the role of the Centralized Service Facility
- Identify the impact of the Mid-Term IAS Architecture on AUTODIN II design (PSN, terminals, protocols, System Control)

- o Define IAS security subsystem

- o Evaluate options for expansion of AUTODIN II overseas

The preferred architecture for the Mid-Term IAS presented in this report meets all of the major objectives of the IAS program. In addition, the recommended transition approach demonstrates that the preferred architecture can be achieved in an orderly evolutionary process from the current AUTODIN through the near-term into the mid-term and eventually beyond into the far-term.

5. SCOPE

This report presents the results of the IAS Architecture definition process applicable to the mid-term. Previous effort in this process was directed toward identification and analysis of implementation alternatives for the near-term (1978-1983). This near-term work, described in the IAS Architecture Report of December, 1977, was intended to shape decisions on the implementation and/or use of existing and readily available hardware/software components in order to achieve a near-term capability. The mid-term architecture analyses, by contrast, were directed toward the development of an overall, top-down system architecture, and the definition of new system elements required to support this architecture. This report is intended to provide guidance to DoD in planning and programming for a new family of terminals, and other hardware/software components of the IAS.

The overall IAS program milestones are identified in Figure 2. As indicated in this figure, the mid-term architecture definition will continue through FY 79 in order to provide necessary functional specifications for the Common Family of AUTODIN Terminals to include the Inter-Service/Agency AMPE.

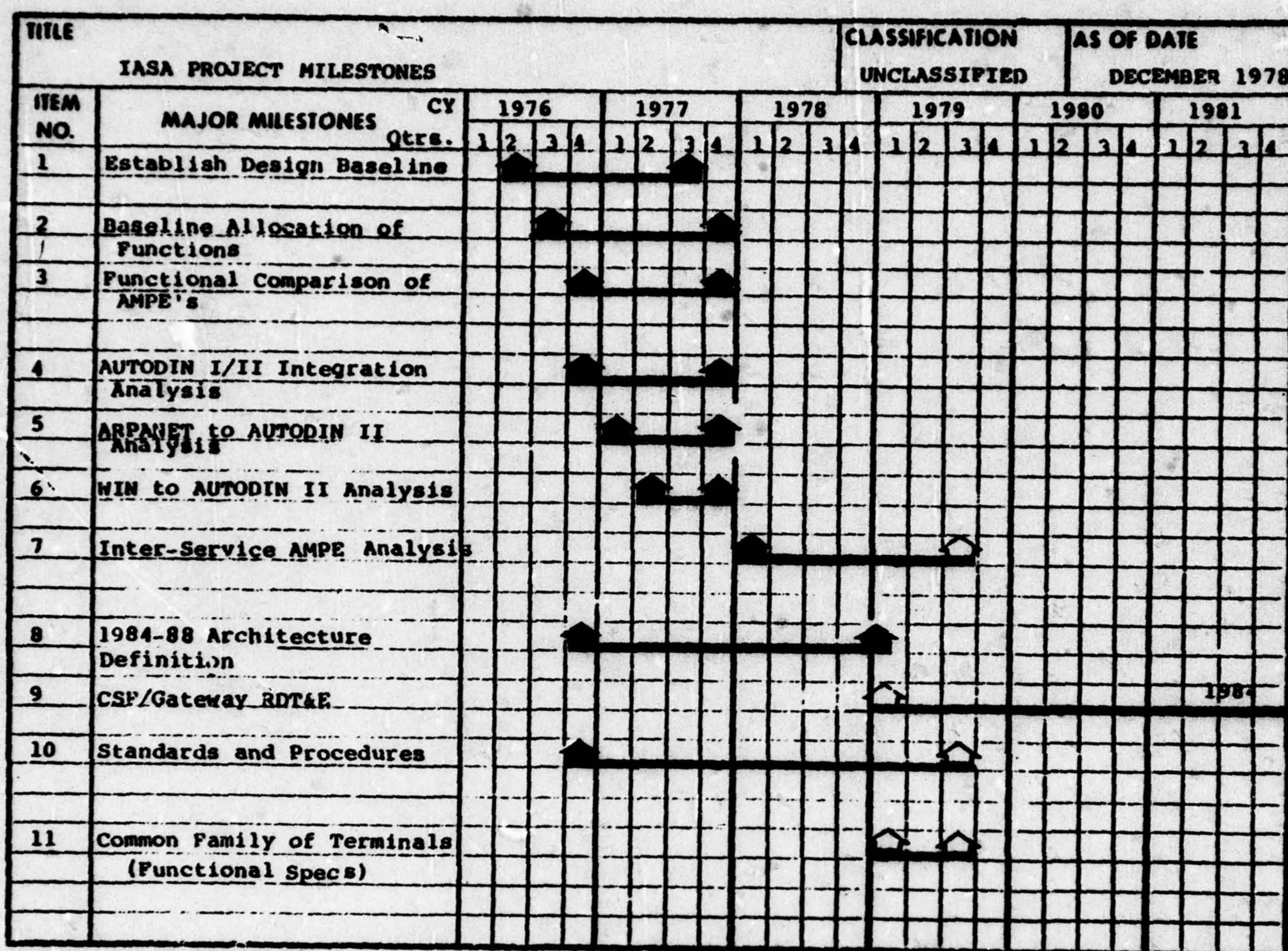


Figure 2. IASA Schedule

SECTION II

GENERAL ARCHITECTURAL ALTERNATIVES FOR THE MID-TERM IAS

1. THE NEAR-TERM IAS ARCHITECTURE OF 1983

In order to evaluate the alternative architectures available for the Mid-Term Integrated AUTODIN System (1984-1988) it is necessary to understand the evolutionary changes in the AUTODIN I/II networks that will result from implementation of the Near-Term IAS Architecture. It is recognized that the evolutionary nature of the changes in the AUTODIN I/II networks preclude a single point description of this period of rapid development and implementation. However, for purpose of this report it is useful to represent the cumulative network changes as a single description referred to throughout this document as the Near-Term IAS Architecture or the 1983 Architecture. This conceptual single point description of the Near-Term Architecture for the Integrated AUTODIN System represents a point of departure for all subsequent mid-term architecture definition efforts.

a. General Description. The Near-Term Integrated AUTODIN System Architecture will result from evolutionary developments of both the existing AUTODIN I narrative/record network and developments under the AUTODIN II, Phase I packet switched network. By the end of the near-term (1983) interactive, query/response and bulk data service among host computers and a variety of terminals will be provided through a network of AUTODIN II packet switch nodes (PSN). During the near-term, up to four of the current CONUS AUTODIN I ASCs will have been closed. Common-user narrative/record service to all DoD components world-wide will be provided by a network of MILDEP/ Agency Automated Message Processing Exchanges (AMPE) and terminal equipment supported by the remaining ASCs in CONUS and at least seven ASCs overseas connected via a combination of AUTODIN II PSN backbone trunks and remaining inter-ASC trunks. Interface between AUTODIN record/data users and tactical/allied users will be accomplished by designated ASC interfaces to the NATO NICS TARE and AN/TYC-39 automatic message relays. As will be seen in subsequent descriptions, the fully integrated end-to-end common-user network envisioned for the Integrated AUTODIN System will not be achieved by the end of the near-term. The 1983 IAS, therefore, is best described as a consolidated DCS subsystem consisting of two major networks, the AUTODIN I narrative/record network and the AUTODIN II, computer communications oriented network. The IAS implementation efforts throughout the near-term will result in a considerable degree of sharing of assets between these major networks as well as significant

standardization of user terminals and local message processing equipments. More importantly, the near-term developments will lay the groundwork for the total integration of these two networks that will take place throughout the mid-term time period. The remaining paragraphs in this section describe the 1983 Architecture in more detail.

b. Major Subsystems of the 1983 Architecture.

(1) AUTODIN I. The Automatic Digital Network (AUTODIN) I is a store-and-forward switched network of the Defense Communications System (DCS) which functions as a single integrated world-wide, high-speed, computer-controlled, general-purpose communications network, providing secure record communications service to the Department of Defense (DoD) and other Federal agencies. AUTODIN I has been operational for approximately 16 years and has undergone numerous enhancements and expansions required to meet the growing DoD requirements for data/record communications. In addition, several additional enhancements and improvements are currently in process and/or planned for the AUTODIN I to keep it viable and responsive to the needs for narrative/record communications into the 1980s.

CONUS. An expanded memory system was recently installed at all eight CONUS ASCs as well as at the Hawaii ASC. This memory system, which consists of four disc units and two mini-computers at each switch, frees up core space for additional programs and provides faster cycle time than the old mass memory units. The new software package included with this system will also allow for a larger operating program through program overlays. Another CONUS AUTODIN support project is replacement of the magnetic tape and mass memory units with disc units at each leased ASC. In addition to significant cost savings, this enhancement will provide a direct, high-speed, channel interconnect to the AUTODIN II PSNs. This will permit utilization of the PSN network for digital trunking between ASCs.

Overseas. To meet currently forecasted operational requirements and to replace/refurbish worn out subsystems of the overseas AUTODIN I, DCA has also initiated several enhancement projects. These are: memory-memory control replacement program; input/output controller, card reader, and high-speed printer replacement; tape subsystem replacement; and patch and test facility upgrade. These enhancements will insure operation of the overseas AUTODIN through at least 1985.

(2) AUTODIN II. The AUTODIN II is a general purpose data communications packet switched network for integrating the teleprocessing and record communications needs of DoD into a single digital backbone system. AUTODIN II Phase I will achieve an Initial Operational Capability (IOC) in FY 1980.

CONUS. The design of the AUTODIN II system is based on packet-switching technology with the intent to use fully those aspects of the ARPANET design technology (such as proven algorithms) that are applicable to the new system. The system will employ a short data handling unit, or packet of bits, to accommodate man-computer, computer-computer and/or computer-terminal data traffic.

Each AUTODIN II packet switch (PSN) will: route and distribute packetized traffic (interactive, query/response, record, and bulk data) over a full duplex wide-band trunking network; electrically interface with the AUTODIN I system through CONUS ASCs; terminate up to 150 lines (both individual and multiplex) per switch with a capability to service up to several hundred data subscribers and accommodate dial-up access lines for low volume subscribers and emergency restoration.

The initial AUTODIN II network will consist of three PSNs at Ft. Detrick, Tinker AFB, and McClellan AFB with a Network Control Center at Headquarters DCA. The acceptance of this three node network establishes the FY 1980 IOC. Subsequently, a fourth PSN will be added at Gentile AFB. The growth of the network from that point will depend on user requirements and user ability to provide the software and hardware interfaces needed to connect to the network. It is envisioned that the network service will grow incrementally, as required, to meet additional requirements.

There are two basic types of subscribers to the AUTODIN II: network hosts and terminals. Hosts are computers capable of simultaneously conducting multiple conversations with other hosts or terminals. Host computers, in general, are the centers of major ADP teleprocessing systems and are major sources of network traffic.

Terminals are defined as either bit or character oriented devices capable of conducting a conversation with only one destination at a time. Terminals may operate in interactive (I/A), query/response (Q/R), bulk, or narrative message applications. Terminal devices include computer peripheral controllers and intelligent or unintelligent input-output devices. The PSN will

interface with terminals so as to minimize the hardware and software impacts of these users. Multiplexers are used extensively in this network to minimize the cost for access lines.

In a typical AUTODIN II network data flow, the traffic source (computer, terminal, or AUTODIN I ASC) will present a data segment to the source PSN. The source node will accept traffic one segment or character at a time from the subscriber, make prescribed control, security and community of interest checks, format the segment into a packet for network transmission and send each packet separately into the network on the appropriate trunk. Intervening nodes will relay the data packets. The destination node will reform each packet into subscriber deliverable traffic in the form of a segment (or characters), perform outgoing validation checks, deliver the segment or characters to the destination terminal and acknowledge receipt.

As a major subsystem of the DCS, AUTODIN II must provide service at all levels of security from unclassified to Top Secret, Special Intelligence. To meet this need, the AUTODIN II, Phase I communication links and switch facilities will be secured to the highest classification level transmitted, and will be capable of being compartmented by use of transmission control codes (TCC) and virtual logical channels. Each data packet will be verified as to the authorized security level and community-of-interest of both the sender and receiver.

Overseas. Current DCA planning for AUTODIN II provides for achieving service on a worldwide basis via overseas PSNs as early as FY 1981 but no later than FY 1983. Prior to fielding PSNs, service will be provided solely via multiplexers. Initial PSNs will be located, one each in Europe and the Pacific. Additional near-term overseas service may be provided through continued use of local multiplexers via intercontinental trunk (probably satellite). Final decisions on overseas will be made in the near-term.

c. Network Elements. The major architectural elements that exist in the 1983 Architecture are derived from the AUTODIN I/II networks. These elements are described in the following subparagraphs.

(1) Packet Switch Node (PSN). The PSN is being developed under the AUTODIN II, Phase I program to provide backbone switching for both the AUTODIN II and AUTODIN I subsystems. A simplified functional block diagram of the PSN is illustrated in Figure 3. As indicated in this figure, the PSN includes the following major subsystems:

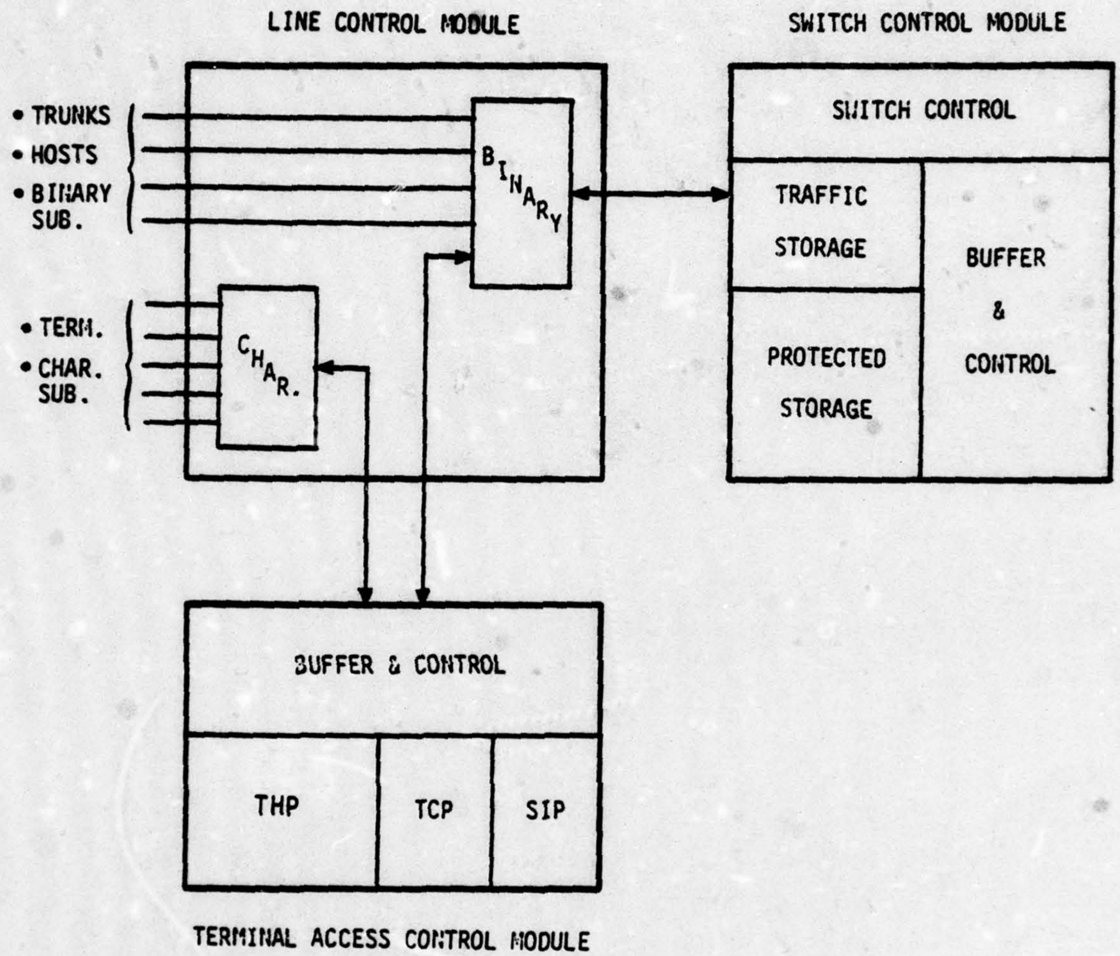


Figure 3. PSN Functional Block Diagram

Line Control Module (LCM). The LCM provides the communications interface and protocol functions necessary to interface to trunks as well as host computers and terminals terminated at the PSN. The LCM transfers data to and from trunks in the form of packets; to and from host computers and other binary format terminals in the form of binary segments, and to and from character oriented terminals in the form of characters. The LCM exchanges data with the SCM in the form of both packets and segments as needed.

Switch Control Module (SCM). The SCM performs the basic packet switching function within the PSN. The SCM accepts binary segments or packets from the LCM, processes the routing and control information contained in the data, and returns packets or segments to the LCM.

Terminal Access Control (TAC) Module. The TAC is included in the PSN to permit character oriented terminal subscribers (both AUTODIN I and II) to utilize the PSN. The TAC includes a Terminal Host Protocol (THP), Transmission Control Protocol (TCP) and a Segment Interface Protocol (SIP) which allow conversion between character format data and binary segment data for processing by the SCM. The TAC capability of the PSN can be implemented outside the PSN itself at remote terminal or host locations. In this case the remote TAC interface to the PSN appears to be a binary segment format. The technical features and performance of the PSN are described in the System Performance Specification, (Type A) for the AUTODIN II, Phase I.

(2) AUTODIN Switching Center (ASC). The 1983 architecture will utilize eleven AUTODIN I ASCs. The 4 ASCs remaining in CONUS will be colocated with AUTODIN II PSNs. These ASCs will terminate local subscribers and, by means of special TAC "cut-through" arrangement at the PSNs, be able to terminate remote subscribers via the PSN backbone. This arrangement is described further in Section III (paragraph 2 b). In the 1983 architecture, direct trunking between ASCs will also be used to provide connectivity among allied/tactical users, overseas ASCs and ASCs colocated with PSNs both in CONUS and overseas.

(3) Automated Message Processing Exchange (AMPE). The 1983 architecture will include a large number of MILDEP/Agency operated AMPEs, such as the AMME, LDMX, NAVCOMPARS, AF AMPE, and Streamliner. These AMPE equipments will provide local message processing and communications concentrator functions for narrative/record users.

AMPEs will continue throughout the near-term to be homed on designated ASCs, either through direct ASC termination or through a Terminal Access Controller (TAC) interface at a PSN.

(4) Near-Term Inter-Service/Agency AMPE (Near-Term I-S/A AMPE). Toward the end of the near-term some degree of AMPE standardization will be achieved through limited introduction of a Near-Term I-S/A AMPE beginning in 1982. This "standardized" AMPE, while not capable of performing the complete set of all I-S/A AMPE functions, will perform an agreed upon set of functions in an agreed upon standard way and will be capable of satisfying the service requirements for some percentage of subscribers of all the services and agencies. This Near-Term I-S/A AMPE is envisioned to be based on multiple mini-processor technology. The Near-Term I-S/A AMPEs will be homed on one or more ASCs throughout the near-term as the service and agency AMPEs are now.

(5) Host Computer. Major high volume computer facilities in user communities such as WWMCCS and SACDIN will interface directly to PSNs in the Near-Term Architecture. These are computers capable of simultaneously conducting multiple conversations with multiple destinations. The interface will use binary segment leaders principally in Mode VI. These hosts are centers of major ADP activity and are major sources of network traffic. (Note: small volume ADP systems will probably be categorized as terminals and be connected to ASCs or PSNs in a standard mode; or connected to AMPEs or Near-Term I-S/A AMPEs in either a standard or subscriber specified mode).

(6) Terminal. A wide variety of terminals will exist in the 1983 architecture. Typical characteristics of the AUTODIN I type and AUTODIN II type terminals anticipated in this period are shown in Table I. Terminals are defined as character oriented devices capable of conducting a single coversation and range from teletypewriters up through small computers.

(7) Multiplexer. Multiplexers will be used in the 1983 architecture wherever practical in order to effect transmission efficiency and/or cost reduction.

d. 1983 Architecture Configuration. The anticipated 1983 architecture is illustrated in Figure 4. This schematic diagram illustrates the generic configuration of network elements both in CONUS and overseas. This basic configuration is described in the following subsections.

TABLE I. 1983 ARCHITECTURE TERMINAL CHARACTERISTICS

EXISTING AUTODIN I TERMINALS

Types - teletypewriter, card, magnetic tape, facsimile, multimedia, computer interface, AMPE

Protocols/Modes - I, II and V

Codes - ASCII, ITA#2, Fieldata

Speeds - 45 thru 4800 bps

Formats - JANAP 128, ACP 127, DOI 100/103

ANTICIPATED AUTODIN II TERMINALS

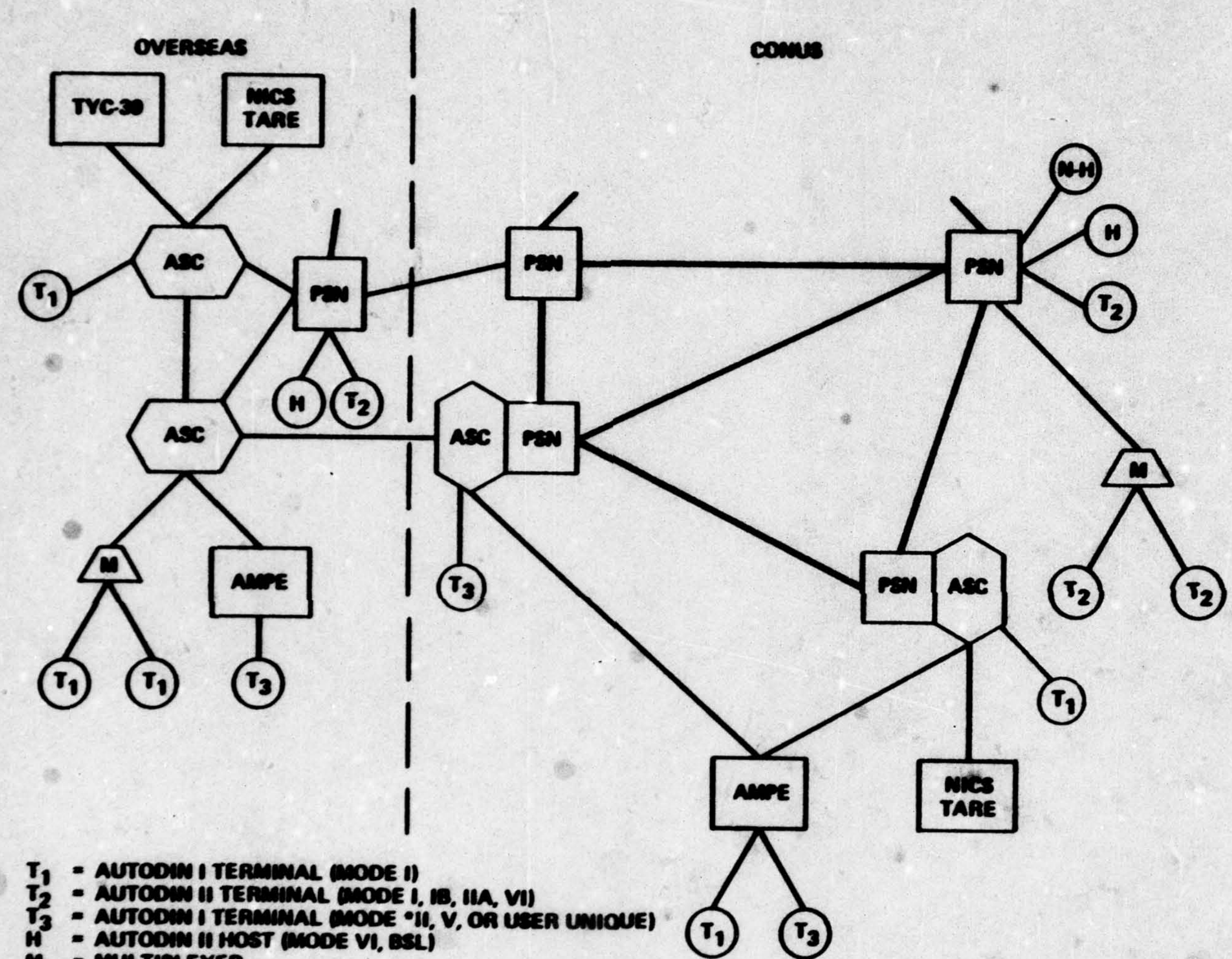
Types - teletypewriter, card, magnetic tape, facsimile, CRT, sensors, multimedia, host computers

Protocols/Modes - I, IB, IIA, VI link protocols and end-to-end host protocols

Codes - ASCII, others (transparent to network)

Speeds - 110-56k bps

Formats - binary and character segment formats, message formats transparent to network



T_1 = AUTODIN I TERMINAL (MODE I)
T_2 = AUTODIN II TERMINAL (MODE I, IB, IIA, VI)
T_3 = AUTODIN I TERMINAL (MODE *II, V, OR USER UNIQUE)
H = AUTODIN II HOST (MODE VI, BSL)
M = MULTIPLEXER
N-H = NETWORK FRONT-END (NFE) CONNECTED HOST

* NOT ALL MODES AVAILABLE AT ALL NODES

Figure 4. Near-Term IAS Architecture

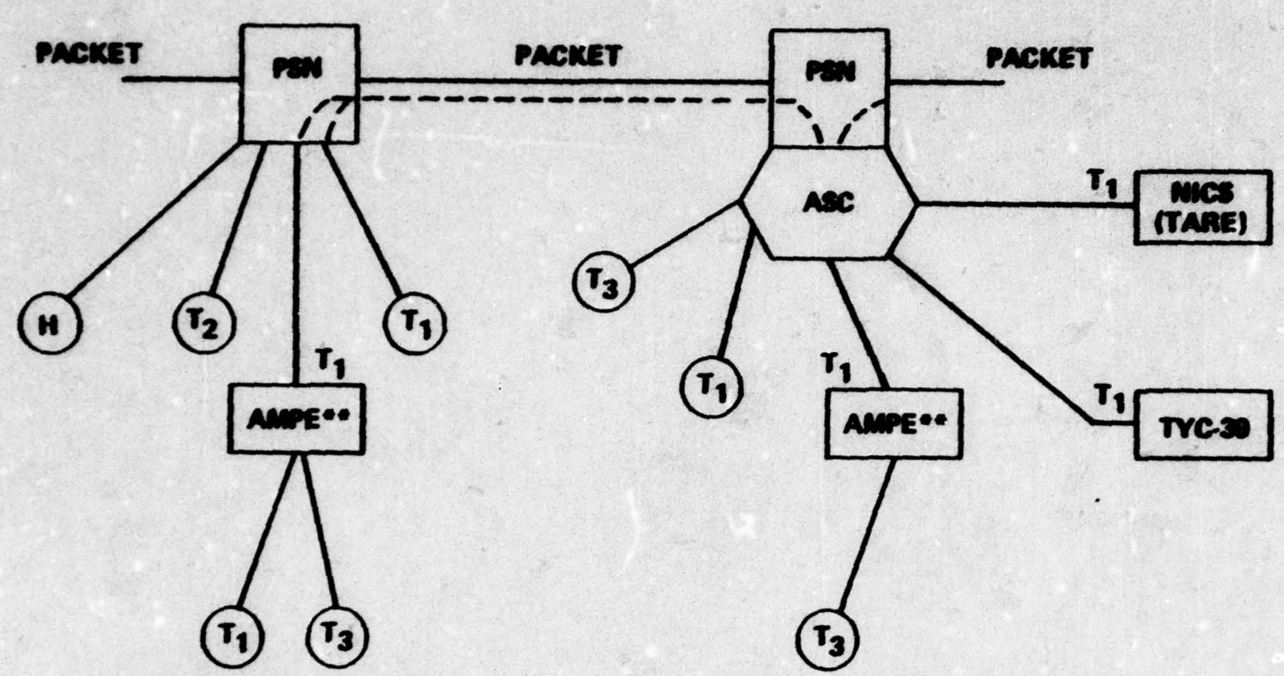
(1) CONUS. The anticipated backbone in CONUS will include up to eight PSNs with four colocated ASCs. The trunk network connecting these PSNs will be sized both for survivability and speed of service considerations.

The access region in CONUS will consist of MILDEP/Agency unique AMPE and Near-Term I-S/A AMPE equipments and an assortment of AUTODIN I and AUTODIN II type terminals connected via local communications facilities to either AMPE, Near-Term I-S/A AMPEs, ASCs, or PSNs. It is not anticipated that the current AUTODIN I subscriber network within CONUS will change significantly during the near-term. The major change in the access area during the near-term therefore, will be represented by the introduction of a significant number of AUTODIN II host computer and subscriber terminals.

(2) Overseas. The overseas backbone in the 1983 Architecture will depend heavily upon existing ASC assets. Although implementation of overseas PSNs is planned for the near-term, significant replacement of ASC operation overseas will probably not be accomplished by the end of the near-term time period. A significant feature of the overseas backbone will be the direct interface between allied/tactical users and ASCs (at least two NATO interface trunks are also anticipated for CONUS). The access area overseas is expected to be dominated by the existing AUTODIN I terminals (including AMPEs). The introduction of AUTODIN II terminal and host computer interfaces overseas is dependent upon the introduction of packet service overseas. It is anticipated that by 1983 this service will be readily available in Europe and to a lesser degree in the Pacific.

As evidenced by the schematic diagram of Figure 4 and the preceding descriptions, although full integration of the AUTODIN System will not be possible in the near-term, significant sharing of backbone assets will have been accomplished. In addition, the consolidation/closure of ASC sites both in CONUS and overseas should significantly reduce cost of operation and maintenance (O&M) associated with the total AUTODIN System. However, the 1983 architectural configuration does represent significant potential problems in the area of survivability through the introduction of choke points in the total network operation. It must be recognized therefore, that the 1983 architecture is not an end in itself, but rather a conceptual milestone in the continued evolution of the Integrated AUTODIN System.

e. Connectivity in the 1983 Architecture. The major interfaces that will exist in the 1983 architecture are illustrated in Figure 5. The basic link protocol and interface characteristics of the 1983 architecture are described in Table II.



T_1 = AUTODIN I MODE I
T_2 = AUTODIN II MODES I, IB, IIA, VI
T_3 = AUTODIN I MODE II, V OR USER UNIQUE*
H = AUTODIN II MODE VI, BSL
---- REMOTE HOMING VIA "CUT THROUGH"

* NOT ALL MODES AVAILABLE AT ALL NODES
** OR NEAR-TERM I-S/A AMPE

Figure 5. Near-Term Connectivity

TABLE II. 1983 ARCHITECTURE CONNECTIVITY

CONNECTION	LINK PROTOCOL
PSN-PSN	Binary Packet
PSN-ADP Host	Mode VI, Binary Segment Leader (BSL)
PSN-ASC	Mode VI BSL
PSN-Terminal (Type II)	Mode IB, II or VI Character via Terminal Access Controller (TAC)
PSN-AMPE/Terminal (Type I)	Mode I, Character (via TAC)
ASC-ASC	Mode I, DIN I (Switch-to-Switch)
ASC/AMPE-Terminal (Type I)	Mode I, II, V, DIN I (Terminal)
ASC-NICS (TARE)	Mode I, DIN I (Terminal)
ASC-TYC-39	Mode I, DIN I (Terminal)

f. Tactical Interfaces. The two principal tactical interfaces for the Integrated AUTODIN System are anticipated to be operational by 1983. These interfaces are the AN/TYC-39 Automatic Message Relay developed under the TRI-TAC program and the NATO Improved Communications System Tactical Automatic Relay Equipment (NICS/TARE). Interface to both of these systems in the 1983 Architecture will be accomplished via direct connection to designated ASCs. (It should be noted that while ASCs are the preferred connection point, any access node with a compatible interface could be used.) Overseas both the AN/TYC-39 and the NICS/TARE interface will be accomplished through designated ASCs. In CONUS one or more of the colocated ASC/PSN sites will be designated as the NATO interface. It is anticipated that both the NICS/TARE system and the AN/TYC-39 relay will employ an AUTODIN I, Mode I, terminal interface and that this protocol will provide the basic access mechanism. Although these interfaces are not considered optimal for the eventual integrated system operation, it is not considered feasible to accomplish significant protocol/interface modifications within the time constraints of the near-term. Therefore, implementation of new access arrangements for tactical/allied users will be accomplished in the mid-term.

g. Security. The 1983 architecture will depend upon link-by-link encryption similar to that employed in the current AUTODIN I System. The cryptographic equipments used for this purpose will include the existing KG-13 and KG-34 as well as newer devices such as the KG-84. Key variable distribution for these equipments will continue to be off-line and essentially a manual operation.

In addition, the AUTODIN II protocols will employ security level and transmission control codes in message headers to enhance the protection and separation provided for user information in the PSNs.

The current consolidation of special intelligence (SI) and general service (GENSER) traffic within the AUTODIN I ASCs permits a single terminal (e.g., AMPE) to transmit and receive SI and GENSER traffic. However, the terminal must operate in an SI accredited environment in system high mode with SI-cleared operators. By 1983 efforts will be complete to consolidate SI and GENSER traffic into Near-Term I-S/A AMPEs which can be certified to joint DIA/NSA criteria.

h. Operation. Procedures and protocols utilized in the 1983 architecture for narrative/record message operation will be basically unchanged from the current AUTODIN I syst~m. As discussed earlier, AMPE and terminal equipments will have a designated home ASC. This ASC will provide the same terminal support and message processing functions as in the current system. Precedence and preemption processing will remain unchanged. Current message formats (JANAP 128, ACP 127, DOI 103) will be employed as well as the DD-173 joint message form and a joint plain language address directory. The three principal modes of operation identified as AUTODIN I standards (Mode I, Mode II, and Mode V) will remain in common use. Procedures and protocols associated with these modes of operation will be essentially unchanged for narrative/record users.

Procedures and protocols for computer oriented data users of the 1983 AUTODIN II network will be developed under the AUTODIN II program. At least four major link protocols (I, IB, IIA, and VI) as well as an end-to-end host protocol are defined for the AUTODIN II system (Reference b). AUTODIN II binary and character formats as well as special message formats for data users will be well defined by the 1983 time period. In general, it is anticipated that AUTODIN II subsystem implementation will be esentially complete within the 1978-1983 time frame. Operating procedures and protocols will be well established and provide a sound basis for expansion of service both in CONUS and overseas throughout the mid-term.

i. Summary. As evidenced by the preceding description, the architecture of 1983 will provide an AUTODIN System that is, in general, responsive to the needs of both narrative/record and data users. In defining the next major evolutionary step toward the Integrated AUTODIN System to be taken in the mid-term, the following characteristics of the 1983 architecture should be considered:

- The architecture of 1983 represents a consolidation of two essentially independent networks with significant sharing of backbone assets and two co-existing user communities with distinct operating procedures, access arrangements and equipment inventories.

- The architecture of 1983 represents an increase in the standardization of AMPE and terminal operation/configuration through introduction of Near-Term Inter-Service/Agency AMPEs.

- The AUTODIN system of 1983 will provide significantly improved performance and service for data users through the capabilities of the AUTODIN II subsystem.

- o The architecture of 1983 represents little or no real improvement in system survivability, security, or operational flexibility over the current AUTODIN I system for narrative/record users.

- o The AUTODIN system of 1983 represents significant improvement in cost effectiveness as a result of the closure of at least four CONUS ASCs and colocation of ASC and PSN sites.

As a result of these and other architectural considerations, it is clear that the architecture of 1983 does not represent an acceptable conclusion to the integration process. Therefore, the need for continued evolution to a Mid-Term Integrated AUTODIN System Architecture is clear. In the next section, the process of defining alternative architectures for the mid-term is initiated with the discussion of the constraints on the mid-term architecture.

2. CONSTRAINTS ON THE MID-TERM IAS ARCHITECTURE

The mid-term architecture for the Integrated AUTODIN System (IAS) will provide an architectural framework for the evolutionary development of the Automatic Digital Network (AUTODIN) during the period 1984-1988. The IAS architecture is not intended to represent a new system that must be developed and superimposed on existing common user DoD systems in a competitive or duplicative manner. It is rather intended as a vehicle to guide the evolution of DoD data telecommunications towards a more secure, survivable, efficient, and cost effective means of satisfying both narrative/record and data communications requirements throughout the 1980-1990 time frame. Consistent with this philosophy, the Integrated AUTODIN System architecture for the mid-term is necessarily constrained in its scope and direction. Coincidentally, the process of defining the Mid-Term Architecture for the IAS is constrained to consider only those architectural alternatives which are technically and economically feasible within the mid-term time frame, consistent with the objectives of the Integrated AUTODIN System Architecture, and finally, consistent with the evolutionary philosophy of the Integrated AUTODIN System. The following subsections present some of the principal constraints on the mid-term architecture and identify the implications of these constraints on the architecture definition process.

a. Current AUTODIN I Inventory Assets. Currently installed AMPEs and terminal equipments of the AUTODIN I network as well as those installed during the period 1978-1983 will have a significant useful life extending into (and in some cases through) the mid-term time frame. The evolutionary implementation of the IAS precludes the

wholesale replacement of these equipments during the mid-term. Therefore, the Mid-Term Architecture must provide for support of AUTODIN I, Mode I, character format terminals and AMPEs throughout the mid-term time frame. The implication of this constraint is most significant upon the functional definition of the nodal elements which must interface these current inventory AUTODIN I AMPEs and terminals. In addition to providing the obvious link protocols, the nodal elements required to support surviving AUTODIN I subscriber equipments must also provide all terminal support functions formerly provided by the ASCs. This has the effect of defining the minimum functional capability of these nodal elements. If and when AUTODIN I service(s) (e.g., guaranteed sequential bulk delivery) can be accommodated by an AUTODIN II service, then and only then will the AUTODIN I service be phased out.

b. Current AUTODIN II Development Status. The currently planned AUTODIN II will provide 4 PSNs with options for up to 4 additional PSNs. This network of up to 8 PSNs will provide the basic backbone for the Mid-Term Integrated AUTODIN System. Based on the early IOC and the advanced degree of definition of network operating modes, protocols, and interfaces, it is not considered feasible to significantly change the design of these elements. Therefore, the Mid-Term IAS Architecture will be based upon utilization of these PSNs with minimum if any modifications.

c. Inter-Service/Agency AMPE Program Status. In a recent memorandum, the ASD (C3I) reiterated the objectives of the IAS Architecture program and established the need for an Inter-Service/Agency AMPE (I-S/A AMPE) Program as an initial step toward successful implementation of an Integrated AUTODIN System (Reference c). The proposed program envisions a Near-Term I-S/A AMPE that would be available as soon as 1982 and a full capabilaity I-S/A AMPE family fielded beginning in 1984/1985. This I-S/A AMPE program provides a viable mechanism for providing many of the functional capabilities required in the Mid-Term IAS Architecture. Therefore, the Mid-Term IAS Architecture definition is based upon the assumption of the availability of such a full capability I-S/A AMPE family in time for mid-term use.

d. Available Technology. Based on current DoD experience with new technology introduction, and the development cycle required for communication system implementation, new network elements to be introduced during the mid-term must be based upon currently available technology. This precludes the introduction during the mid-term of two of the principal long-term architectural objectives identified by

DCA in previous studies, i.e., integrated voice and data and the use of multiple access satellite broadcast capability. However, the long-term promise of these technologies, and the probability of their successful development cannot be ignored. Therefore, these advanced technologies are assumed to be available for Far-Term IAS implementation (Post 1988). In addition, the mid-term architecture definition will consider the impact of this eventual far-term evolution on the Mid-Term Architecture itself. This will insure that near-term architectural decisions do not preclude successful continued evolution of the IAS.

3. APPROACH TO MID-TERM ARCHITECTURE DEFINITION

As noted earlier the Integrated AUTODIN System Architecture definition process is being conducted in three parts corresponding to the three time periods of the IAS implementation:

- Near-Term (1978-1983)
- Mid-Term (1984-1988)
- Far-Term (Post 1988)

The architecture definition process performed in support of the near-term planning was necessarily concentrated on identification and analysis of implementation alternatives. This analysis was limited to consideration of network elements available from the existing AUTODIN I inventory and elements already under development in the AUTODIN II program. Similarly, configuration and connectivity alternatives were limited by the capability inherent in these elements.

The architecture definition process in support of the mid-term is considerably broader in scope than that performed for the near-term from two standpoints: First, because the start of the mid-term (1984) is sufficiently advanced to permit development of new network elements, some degree of functional definition and reallocation is possible. Secondly, as a result of the potential functional redefinition/reallocation at the nodal element level, new configuration and connection alternatives at the overall systems architecture level are possible.

The approach to architecture definition employed for the Mid-Term IAS Architecture reflects these differences from the near-term. In the near-term, architecture definition was issue oriented and

addressed specific options available to the system implementer. The Mid-Term Architecture definition process on the other hand, is aimed toward definition of a top down overall architectural description.

The approach to defining the Mid-Term IAS Architecture was based on the following three analysis efforts:

- Definition of mid-term requirements and operating environment
- Generation of candidate architectures and selection of alternative architectures from among viable candidates.
- Evaluation of alternatives and selection of a preferred architecture

The following sections present the results of these architecture definition analyses.

4. MID-TERM REQUIREMENTS AND OPERATING ENVIRONMENT

This section presents the projected user requirements for the mid-term Integrated AUTODIN System and defines the anticipated environment in which the IAS must operate.

a. Sources. The projected IAS mid-term user requirements were derived from the following source doucments:

- Preliminary IAS Requirements Definition, DCEC, October 1977
- Switch Networks Automatic Profile System, Network Profile (Sample Days)
- AUTODIN II, Phase I Performance Specification, DCS, November 1975
- IAS ARCHITECTURE Report, December 1977
- AUTODIN II, Phase I Business Plan, DCA, November 1976
- AUTODIN II Data Base, DCEC, December 1977
- Information to Support AUTODIN Planning Studies, DCA, August 1977

b. Projected IAS Traffic Input. The projected busy hour average traffic input for the Integrated AUTODIN System in the period 1978-1988 is illustrated in Figure 6. This traffic input is based on projections of the AUTODIN I and AUTODIN II current and projected traffic patterns.

(1) AUTODIN I Traffic. The AUTODIN II Type A Specification (Reference b) estimates the total AUTODIN I traffic input to AUTODIN II PSNs at 4.9 X 10(8) bits per busy hour in 1980. This represents AUTODIN I trunk traffic only since intra-ASC traffic will not be presented to the PSNs. Based on a survey of sample days from the Switch Networks Automatic Profile System, The AUTODIN I local ASC traffic volume averages approximately 1/3 of the ASC trunk traffic volume. Therefore, the total input busy hour traffic from AUTODIN I type subscribers in 1980 is estimated to be 4.9 X 10(8) (trunk) plus 1.6 X 10(8) (local) for a total of 6.5 X 10(8) bits.

The AUTODIN I traffic growth up to 1980 was found to be 11 percent per year based on recent AUTODIN I traffic volumes (Reference d). Since some computer oriented users of AUTODIN I are expected to convert their bulk data traffic to AUTODIN II, a decrease in the rate of growth in AUTODIN I traffic is expected after AUTODIN II is implemented. AUTODIN I type traffic growth, therefore, is projected at 6 percent per year after 1980. These projections result in a total AUTODIN I busy hour input traffic volume of 1.2 X 10(9) bits or an average of 334 kbps in 1988.

(2) AUTODIN II Traffic. The Preliminary IAS Requirements Definition of October 1977 (Reference d) estimates the total AUTODIN II busy hour traffic input (exclusive of AUTODIN I traffic) at 4.74 X 10(9) bits in 1982. A rapid growth in traffic volume to this level can be expected as subscribers are phased into the system between mid-1980 and mid-1982. After 1982, the growth will probably level off to that of a mature system. The increase in the volume of this type of traffic, was, therefore, estimated at 11 percent per year in accordance with the recent growth pattern of AUTODIN I traffic.

The AUTODIN II, Phase I System Performance Specification (Type A) (Reference b) provides estimates for the relative proportions of transactions and average transaction length by traffic type. It also estimates the ratio of computer to terminal input traffic. These estimates were used to derive traffic volumes by transaction type and subscriber type. The results are shown in Table III.

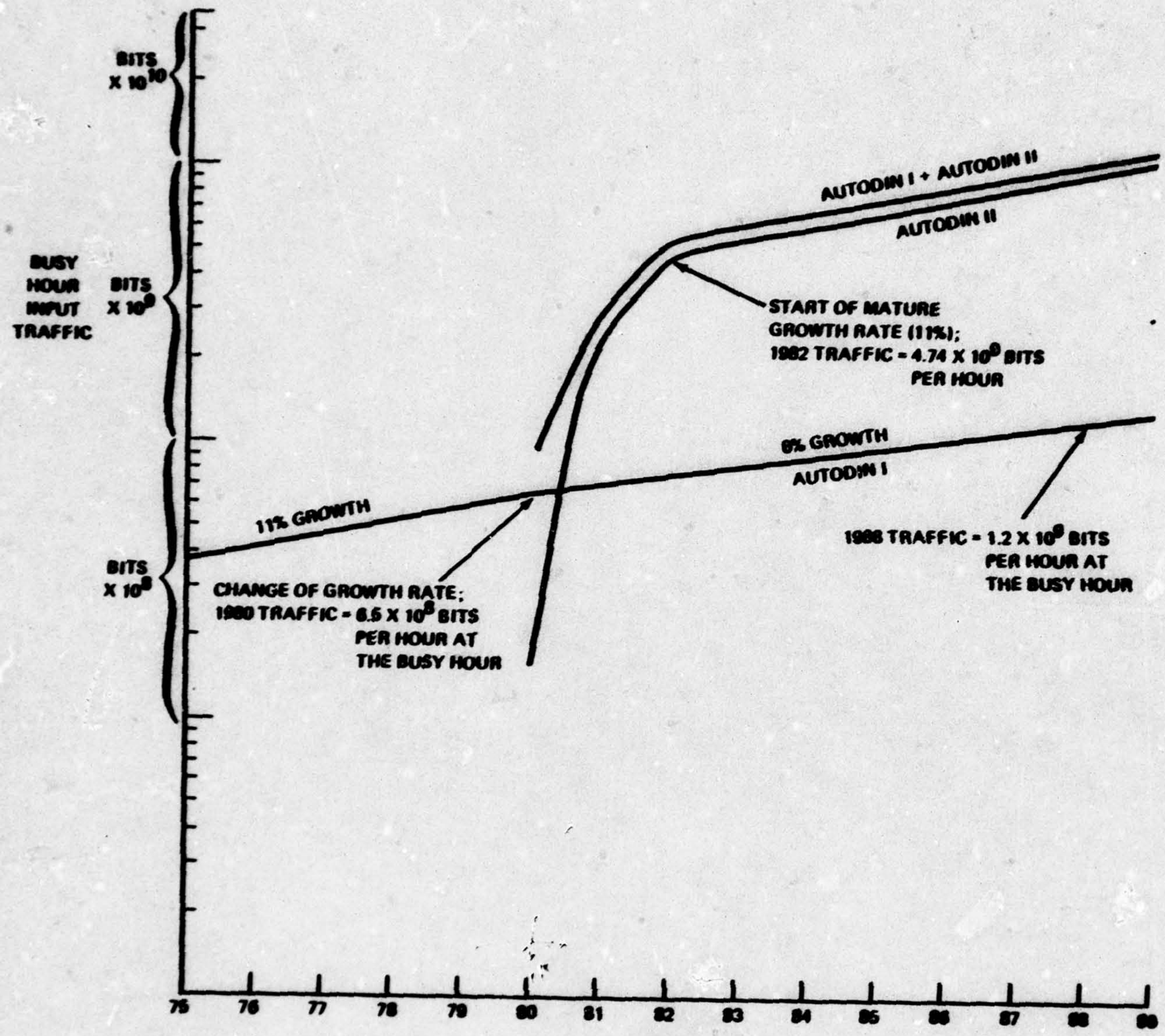


Figure 6. Projected IAS Traffic

TABLE III. AVERAGE BUSY HOUR TRAFFIC INPUT FROM AUTODIN II-TYPE SUBSCRIBERS (1988)

Traffic Type	Input Rate: Terminals (kbps)	Input Rate: Computers (kbps)
Narrative/Record	99	22
Bulk	207	2089
Interactive and Query/Response	5	36
Total	311 kbps	2158 kbps

c. Projected Terminal Population.

(1) AUTODIN I Terminals. The number of access lines connected to AUTODIN I ASCs has remained relatively constant at approximately 900 in CONUS and 500 overseas for the period 1970 to 1978. Adjusting for dual connection of terminals and the estimated AMPE population, the number of AUTODIN I terminals connected to the network is estimated to be approximately 800 in CONUS and 400 overseas. In the near-term the trend toward relocation of terminals behind AMPEs is expected to offset any increases in user requirements for additional terminals. Therefore, the projected IAS AUTODIN I subscriber population throughout the mid-term is estimated at 800 in CONUS and 400 overseas. Additionally, the IAS will ultimately serve today's AMPE remotes.

(2) AUTODIN II Terminals. The number of terminals (exclusive of AUTODIN I) and host computers connected to AUTODIN II PSNs by 1982 is estimated to be approximately 1300 and 150 respectively, based on current validated DoD user requirements (Reference e). The rate of growth in AUTODIN II terminals and computers connected to the network beyond 1982 is dependent on many factors including: user data processing requirements; growth of distributed processing use in DoD; network service offerings; and DoD/MILDEP/Agency policy. For the purpose of this analysis, it is assumed that all validated DoD user requirements for AUTODIN II service identified by 1982, will be satisfied by the initial operational system. Therefore, it is unlikely that a significant number of new requirements will be identified and validated in the 1983-1988 time period immediately following the AUTODIN II implementation. For these reasons, a modest growth rate is anticipated for this period. The projected 1988 AUTODIN II total terminal/host population based on this growth rate is approximately 1800 terminals and host computers.

d. Projected AMPE and I-S/A AMPE Population. During the mid-term time period, most of the current AMPE equipments installed between 1970 and 1980, will reach the end of their useful life. The new Inter-Service/Agency AMPE will be used to replace these AMPEs, as well as to meet new AMPE requirements. However, since the I-S/A AMPE is capable of supporting all service/agency users, at all levels of security, a number of current AMPE sites can be consolidated through joint use of a single I-S/A AMPE. In order to project the total AMPE and I-S/A AMPE population in the mid-term IAS, an analysis of current and planned AMPE sites was performed (See Appendix A). Results of this analysis are summarized in Figure 7. As illustrated in this

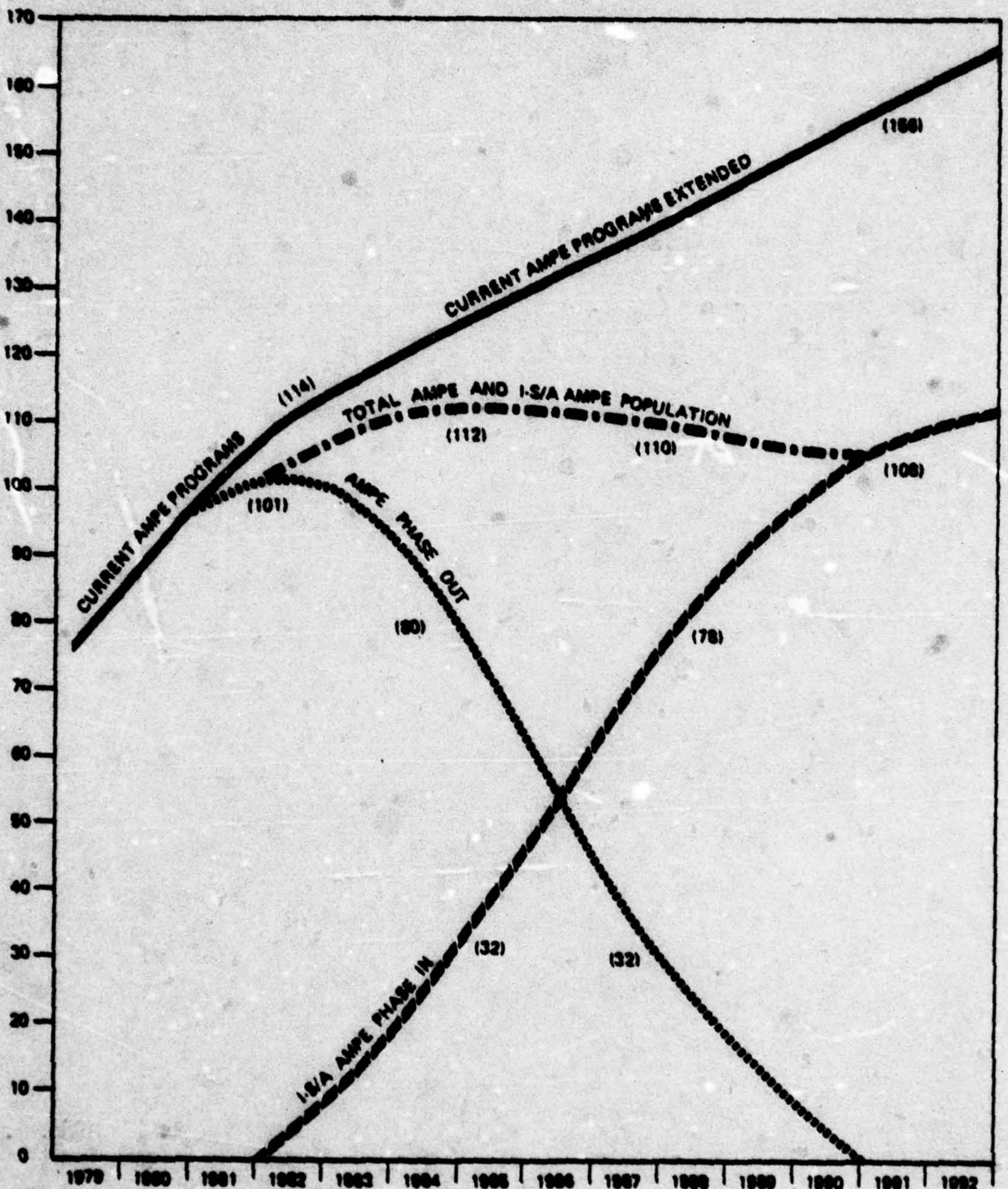


Figure 7. Projected AMPE & I-S/A AMPE Population

figure, total population of AMPE/I-S/A AMPE sites will peak at approximately 112 in 1984 and eventually settle to less than 110 in 1988. It should be noted that this represents approximately 30% less than the number of AMPE sites required if the current AMPE programs were extended at even a modest rate of growth. In addition, the actual number of AMPE installations in the mid-term will be based upon many factors not considered in this analysis, such as specific service/agency operational and survivability requirements. The results of this analysis are, therefore, intended only to support the architecture definition process and are not proposed as a DCA replacement/consolidation policy.

e. Services. The mid-term IAS will provide a full range of data services to most subscribers. These services will include the basic narrative/record services currently provided by the AUTODIN I system, the new computer oriented services defined for the AUTODIN II system, and several new data services, patterned after the ARPANET capabilities that have demonstrated a high degree of user acceptance. As part of the IAS architecture definition process a number of basic services were identified and defined sufficiently to be considered valid requirements. It is anticipated that additional services will be defined throughout the near-term based on user experience with the AUTODIN II system and evolving data needs. The basic IAS mid-term service requirements can be organized into seven categories described in the following subsections.

(1) Narrative/Record Message Transfer. This service includes the secure user-to-user transfer of message traffic provided by the current AUTODIN I System. Using this service a user in the system (properly equipped and within appropriate interest community) may transmit narrative/record traffic to one or more other users. The major service features provided by the network are message accountability and retrieval, multiple/collective address routing, and code and format conversions. This service will be available to all IAS subscribers in some form.

(2) Narrative/Record Message File Retrieval. This service provides storage of message traffic on-line for retrieval upon request from users. Narrative/record messages passing through the network are automatically stored for a prescribed period of time. Other data such as standard forms may be also stored by a user for later recall. The nodal elements which contain the message files perform the processing to store messages, control access to the files and remove messages from the file at user direction or time expiration. The service is presently provided in various forms by some AMPEs in the current AUTODIN I system, and will be provided to all narrative/record subscribers of the IAS.

(3) ADP Transaction Transfer. This service provides both secure and nonsecure interactive, query/response and bulk data transfer as presently defined for the AUTODIN II network. No message processing functions or accountability are provided by the network. Traffic entered into the network contains segment leader information and is routed through the network on a packet basis. Only packet or segment in-transit storage is provided. This service will be available to computer oriented IAS subscribers.

(4) Privacy Service. This service is equivalent to the present AUTODIN I Limited Privacy Service. The traffic is handled as normal narrative/record traffic except that no permanent history or retrieval storage is retained in the system. The service will be available to narrative/record subscribers. (This type of privacy is inherent for ADP transactions since no record of that traffic is retained in the system.)

(5) Informal Message Exchange. This service allows for the exchange of informal or unofficial information among users. It is similar to narrative/record message transfer except limited network functions are provided. An abbreviated, simplified format is used and, therefore, no format conversion is provided, i.e., only in-transit storage is provided. The service is available to all IAS subscribers.

(6) Mailbox Service. Mailbox service allows a user to send messages to a storage location in the network for subsequent retrieval by the addressee. Mailbox service is an augmentation to the informal message exchange service.

(7) Data Teleconferencing. This service allows a conference to be conducted among network subscribers using teletypewriters, CRTs, or similar terminal devices. Conferencing may be simultaneous (conference members exchange transactions on a real-time basis) or delayed (members enter and retrieve transactions at their own convenience). A transaction may be addressed to the conference or to any member of the conference. A network element will control the conference, store conference transactions and respond to requests for conference data or status information from the members. The data teleconference service is an augmentation of the informal message exchange service and will be available to most subscribers.

f. Functions. An important aspect of the mid-term architecture definition process is the identification of network functions and the allocation of these functions to appropriate network elements. As a first step in this process, an analysis was performed in order to

identify existing AUTODIN I, proposed AUTODIN II, and new functions necessary to support future IAS network services. As a result of this analysis 81 specific functions were identified. In order to simplify future discussions of the functional allocation process, it is convenient to categorize these functions as follows:

- ASC Terminal Support Functions - functions performed by ASCs to assist terminal-to-terminal message exchange, e.g., format validation, format/code conversion, accountability, and message storage and retrieval

- ASC Network Functions - functions performed by the ASCs to accomplish routing of messages through the system, e.g., multiple/collective address routing, message control block (e.g., looping control), CARP routing, and precedence processing

- PSN Network Functions - functions performed by PSNs to accomplish routing and control of data flow through the network

- New Network Functions - functions necessary to provide new IAS services, e.g., teleconferencing and mailbox

- Subscriber Termination - provision of network access to subscribers. Includes physical, electrical and link protocol interface. Does not include provision of network services

- Tactical/Allied Interface/Gateway - interface includes physical, electrical and link protocol(s); gateway includes routing functions and support functions (e.g., protocol/format conversion).

As part of the detailed technical analysis performed in support of the IAS architecture definition, the 81 IAS functions were mapped into the general service categories identified in the preceding subsection. In addition, for each alternative architecture, these functions were allocated to the network service elements associated with the alternative architecture. The results of this analysis for the preferred architecture are discussed in Section III of this report.

g. Available Mid-Term Elements. As noted earlier the network elements used in the mid-term IAS must be based upon available technology in order to permit an IOC of 1983-1988 for critical

network services and to permit the rapid replacement of existing AMPEs and ASCs. Candidate elements for the mid-term IAS, therefore, include those elements of the near-term IAS architecture that can be retained through the mid-term as well as new elements that could be developed in time for the mid-term. The candidate IAS elements and their characteristics are identified in the following subsections.

(1) Elements Retained from the Near-Term. The following network elements, implemented prior to or during the near-term will be in use in the Mid-Term IAS:

Packet Switch Node (PSN). The PSNs installed in CONUS and overseas under the AUTODIN II program will be available in the mid-term time frame for use in the IAS backbone. Based on current traffic projections, the PSNs installed in the near-term should be sufficient to accommodate the total IAS busy hour traffic. The need for additional PSNs to be installed during the mid-term in order to support expansion into the far-term and/or growth in the network will be based upon user acceptance and experience with the initial operational network.

Automated Message Processing Exchange (Near-Term I-S/A AMPE, AMME, LDMX/NAVCOMPARS, AF AMPE, Streamliner). As discussed earlier in this section, most of the MILDEP/Agency AMPE equipments will reach the end of their useful service life during the mid-term and will be replaced by standardized Inter-Service/Agency AMPEs. The MILDEP/Agency AMPEs are therefore, not considered principal network elements for the Mid-Term IAS. (Those MILDEP/Agency unique AMPEs retained in the mid-term will be treated the same as other large, automated AUTODIN I terminals in the IAS).

AUTODIN Switching Center (ASC). As discussed in Section I, a principal objective of the Mid-Term IAS Architecture is the closure of the existing ASCs both in CONUS and overseas. Therefore, ASCs will be retained in the Mid-Term IAS Architecture only as required to facilitate smooth and orderly transition.

Subscribers. AUTODIN I and AUTODIN II type terminals and AUTODIN II host computers will be supported through the mid-term.

(2) New Elements Available for the Mid-Term IAS. As part of the architecture definition process a set of generic network elements that could be developed and implemented in the mid-term frame have been defined by DCA:

Central Service Facility (CSF). The CSF is a postulated new centralized network service element that would perform necessary user support functions and/or network functions to accomplish message delivery and provide needed user services. The CSF is accessed via the backbone network and does not directly terminate subscriber equipments. The Central Service Facility would connect to the network via the PSNs through an AUTODIN II host computer (Mode VI BSL) interface. The specific functional capability of the CSF is dependent upon the architectural alternative selected.

Inter-Service/Agency AMPE (I-S/A AMPE). This new element is postulated as a standardized replacement for the existing MILDEP/Agency AMPEs. It would provide a complete set of agreed upon common Service/Agency AMPE functions and have provision for accommodating a limited number of user unique functions. In addition, the I-S/A AMPE would include additional capabilities that permit it to function in the network independent of other network service elements for most simple message exchange transactions. The I-S/A AMPE would, therefore, be less dependent upon intermediate service element processing than the current AMPEs are on the ASCs. The I-S/A AMPE will terminate character oriented terminals of both narrative/record and computer data character oriented users in both standard and user unique modes and will connect to the network through a PSN, an enhanced I-S/A AMPE or both. The I-S/A AMPE will be modular in both hardware and software such that great flexibility will be available to the Services and Agencies in tailoring the I-S/A AMPE for each installation. Thus, number of terminations, throughput and user unique capabilities can vary from site to site. The basic functional capability of the I-S/A AMPE is essentially independent of the architectural alternative selected.

Enhanced Inter-Service/Agency AMPE (I-S/A AMPE(E)). This new element is postulated as a network service element that will be derived from installed I-S/A AMPEs through modular expansion of software (and if necessary hardware). The I-S/A AMPE would, therefore, include all of the functions of an I-S/A AMPE as described above and replace a normal I-S/A AMPE in the network at selected locations. In addition, the enhanced I-S/A AMPEs in the network would provide the additional network functions needed to allow phase out of remaining ASCs and provide new functions allocated by the architecture. The I-S/A AMPE(E) would terminate both narrative/record and computer data oriented users and connect to the network via an AUTODIN II, host computer (Mode IV) interface. The I-S/A AMPE(E), like the I-S/A AMPE, will be modular and thus provide the Services and Agencies great flexibility in tailoring the I-S/A AMPE(E) to meet site requirements. The full functional capability of the I-S/A AMPE(E) depends on the architecture alternative.

Common Family of AUTODIN Terminals (CFT). A new family of terminal equipments is being defined by DCA as part of the IASA program. This common family will include a full range of terminals from simple teletypewriter to highly automated user terminals. The functional capabilities of these terminals will be defined on the basis of user requirements and are independent of the architectural alternatives selected.

h. Element Roles. It should be noted that not all of the candidate architectural elements are utilized in all architectural alternatives. In addition, the roles of some elements are dependent upon the architectural alternatives in which they are used. Finally, as noted above, the specific functional capability of each element is, in many cases, dependent upon the architectural alternative. The next section of this report describes the alternative architectures that were considered for the mid-term IAS architecture.

5. ALTERNATIVE MID-TERM ARCHITECTURES

In order to insure that all potential mid-term architectures were considered, a number of candidate architectures were identified as part of the technical analyses performed in support of the IAS architecture definition. The set of candidate architectures was generated through a sequential decision tree approach based on three major architectural decision levels:

- o Selection of an element set from among the available candidate elements discussed in paragraph 4
- o Allocation of functions among the selected element set
- o Consideration of specific configuration/connectivity options within the architecture (e.g., dual/single homing of nodal elements).

The candidate definition process resulted in the identification of 23 candidate architectures. Upon analysis of the characteristics of the candidate architectures, it was determined that all candidates could be organized into three major classes. Further, it was determined that within each major class the differences between architectures were not sufficient to significantly impact the potential cost and/or performance of the resultant system design. Therefore, three final architectures were selected for evaluation by choosing the most representative and/or desirable candidate from within each major class. These three final alternative architectures are described in the following subsections. It should be noted that all three

architectural alternatives utilize the packet switched node (PSN) as the principal backbone switching element and the Interservice/Agency AMPE (I-S/A AMPE) as the principal access area message processing and communications concentrator element. In addition, all three alternative architectures are designed to provide the required IAS user and network services and functions defined in Subparagraphs 4e and 4f respectively.

a. Alternative I

(1) General. This alternative represents a centralized architecture with little or no hierarchical structure in the access area. All network and user services in this alternative are provided from a relatively small number of service elements connected to the backbone and accessed via the network.

(2) Element Set. In addition to the PSN and I-S/A AMPE, this architecture utilizes the Centralized Service Facility (CSF) as the major network element.

(3) Functional Allocation. As the only available network service element, the CSF in this architecture will contain all functions required to support the network and user services. The CSF will, therefore, include the ASC replacement functions as well as any new network functions. As noted earlier, the CSF will not terminate subscribers.

(4) Configuration/Connectivity. The backbone in this alternative will consist of PSN switching nodes and CSF service nodes. The CSF will be dual connected to PSNs for survivability as well as to minimize service access delay. The access area in this alternative will include I-S/A AMPEs and user terminals. In general, computer data users and host computers will be connected directly to PSNs. Narrative/record users will, in general, be connected to the back side of the I-S/A AMPEs.

(5) Operation. In this architecture most simple user-to-user and user-to-host computer traffic will be routed directly from source to destination via the PSN. All traffic requiring terminal support or network service (e.g., multiple address, format conversion) will be routed through the nearest available CSF for intermediate processing. Back side message routing and local terminal support functions will be provided to narrative/record users connected to the I-S/A AMPEs. All new IAS network functions (e.g., teleprocessing, mailbox) will require connection through the PSN network to the nearest available CSF.

b. Alternative II.

(1) General. This alternative represents a distributed architecture in which user and network services are provided from a common access area element. This results in a very flexible structure in the access area with services accessed both directly and via the backbone network. In addition, this architecture provides the maximum degree of commonality among network elements.

(2) Element Set. In addition to the PSN and I-S/A AMPE this alternative utilizes the enhanced I-S/A AMPE (I-S/A AMPE(E)) defined in Section 4g.

(3) Functional Allocation. The I-S/A AMPE(E) provides all terminal support and network functions in this architecture. In this alternative the I-S/A AMPE(E) replaces the current ASCs and also provides the basis for all new network services.

(4) Configuration/Connectivity. In this alternative the backbone consists of the PSN network. The access area in this architecture consists of the user terminals, I-S/A AMPEs and I-S/A AMPE(E)s. The I-S/A AMPE(E) will be connected directly to the PSN with dual connection in most cases for survivability. In general, the I-S/A AMPE will be connected to both a PSN and an I-S/A AMPE(E). This will provide increased survivability and allow optimal traffic routing for access to needed services. Host computers in this architecture will be connected directly to PSNs. All other subscribers may be connected either to PSNs, I-S/A AMPE(E)s or I-S/A AMPEs.

(5) Operation. Most computer data traffic in this architecture will flow directly from source to destination through intermediate I-S/A AMPEs, I-S/A AMPE(E)s and PSNs. Narrative/record traffic will generally flow through an intermediate I-S/A AMPE(E) and will, therefore, receive necessary terminal support and network service processing en route. All network subscribers will access new network services (e.g., teleprocessing, mailbox) from the nearest available I-S/A AMPE(E).

c. Alternative III

(1) General. This alternative represents a hybrid architecture between the centralized structure of Alternative I and distributed structure of Alternative II. In this architecture, some services are provided by a centralized backbone service element and some services are provided by a distributed access area element.

(2) Element Set. In addition to the PSN and I-S/A AMPE this architecture employs both a Centralized Service Facility (CSF) and an I-S/A AMPE(E).

(3) Functional Allocation. In this alternative the ASC replacement functions (both terminal support and network service) are allocated to the I-S/A AMPE(E) located in the access area. The functions necessary to provide new network services are allocated to the CSF located in the backbone.

(4) Configuration/Connectivity. The backbone in this alternative consists of the PSN network and a small number of CSFs. The CSFs are dual connected directly to the PSNs for survivability and minimum access delay. The access area in this alternative includes subscriber terminals, I-S/A AMPEs and I-S/A AMPE(E)s. The access area connections in this architecture are similar to those in Alternative II.

(5) Operation. The operation of this alternative is strongly affected by the separation of traffic support functions. Depending on the type of traffic in a particular transaction, the data flow may be either directly from source to destination via the PSN backbone network or, depending on the services required, through the appropriate backbone or access area service element. Traffic routing and data flow in this alternative are therefore somewhat more complex than in the other two alternatives.

d. Summary. The basic configuration, nodal element types, and functional allocation for the three alternative architectures are summarized in Figure 8. This figure presents a greatly simplified representation of each architecture. As discussed earlier in this section, these three alternatives represent the three major classes of architectures applicable to the IAS mid-term. Each of these architectures provides the required mid-term IAS services and functions and is consistent with the constraints and anticipated operating environment of the mid-term. In addition, each of these alternative architectures represents a significant departure from the Near-Term IAS Architecture described in Section II, paragraph 1.

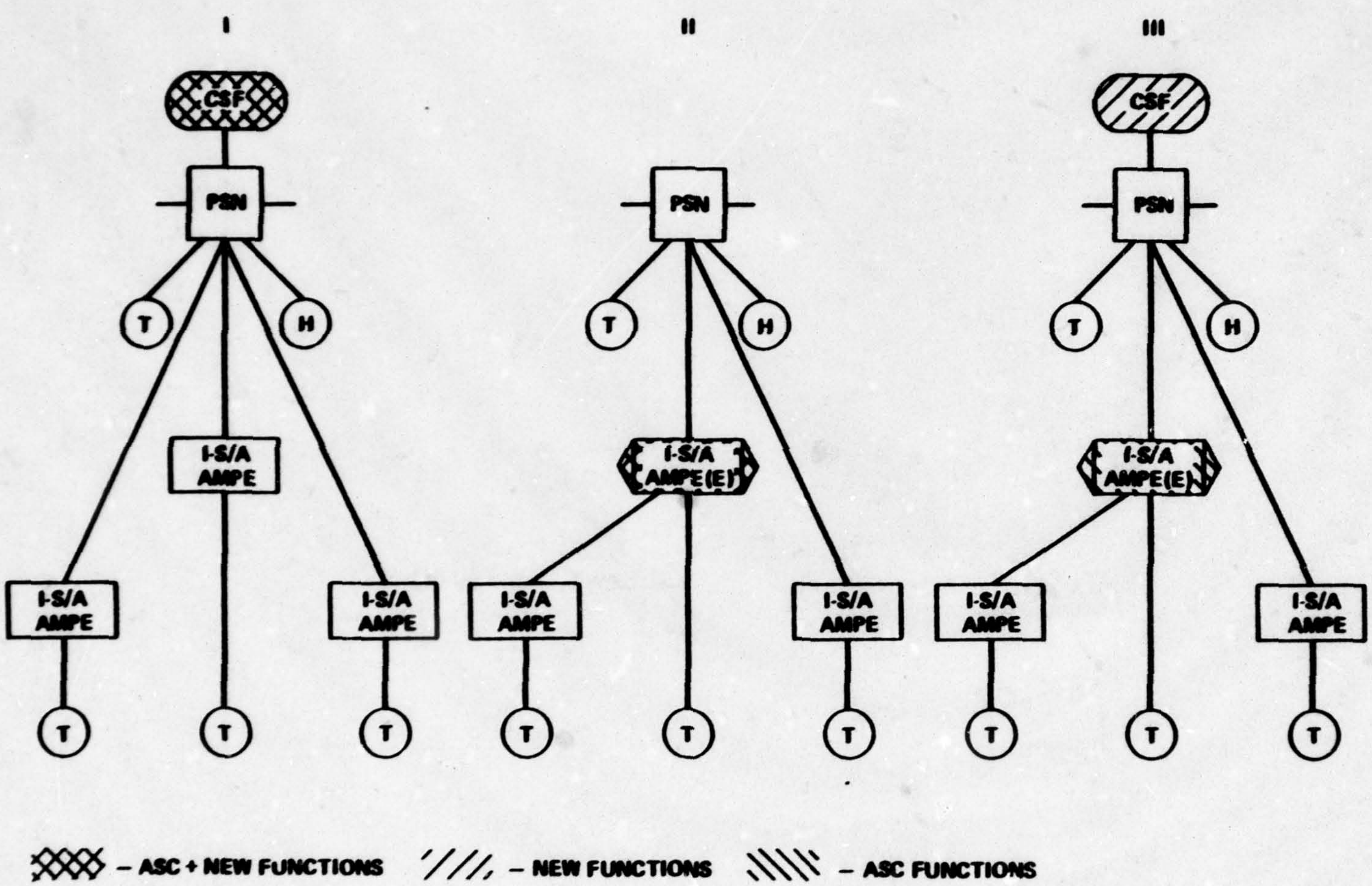


Figure 8. IAS Alternative Architectures

6. EVALUATION OF ALTERNATIVES

In order to determine the preferred Mid-Term IAS Architecture, the three alternative architectures described in Paragraph 5 were evaluated with respect to both technical and cost factors. This evaluation was based on a series of quantitative and qualitative technical analyses performed in support of the IAS architecture definition. In order to provide a high degree of confidence in the final results of the evaluation, the general approach to alternative evaluation was based on the following guidelines:

- Evaluation on the basis of comparative/relative performance vice absolute performance estimates
- Application of quantitative analytic techniques wherever possible and appropriate
- Consideration of all relevant factors in subjective/qualitative analyses
- Careful documentation of factors considered and basis for subjective decision
- Thorough review of analysis methods and results by cognizant DCA/DCEC personnel

Since the eventual performance of any system is difficult to measure at such an early stage of architectural definition; and, since detailed system performance requirements based on future user applications/needs cannot be specified until much later in the system definition/design cycle; and since each alternative architecture is capable of meeting the anticipated future performance requirements through design tradeoffs within the state-of-the-art; the differences between alternative architectures were, in many cases, measured in terms of the difficulty or complexity of meeting performance objectives in given areas based on inherent architecture characteristics. Examples of such characteristics are:

- The number of nodal and transmission delays that must be encountered from user to user/service element
- The number of different nodal elements contained in the network and the degree of commonality among elements

- o The number of operations required to complete a message transfer including intermediate processing
- o The number of elements available/required for user connection/service access.

The technical analyses performed in this evaluation process are documented in Appendix B, C and D. The next subsection describes the evaluation criteria used in these analyses.

a. Evaluation Criteria. Five major evaluation criteria were used for the evaluation of alternative architectures. Within each criterion anywhere from 4 to 10 subcriteria were considered. Within each subcriterion, a number of factors were considered. The following paragraphs define each major criterion and identify the subcriteria and factors considered in the evaluation.

(1) Operational Effectiveness. This criterion addresses the relative efficiency and effectiveness of an architecture for providing the required functional capability. The subcriteria used in this category were speed of service, user motivated interfaces, transmission efficiency, system motivated functions, security and adaptability to overseas. The factors considered in the subcriteria were: speed of service by traffic type (e.g., interactive, query/response, key distribution, mailbox); interface complexity for access to and interaction with network services; transmission overhead by network function (e.g., addressing, normal routing, CARP routing, flow control, error control, system control); complexity of system motivated functions (e.g., system control, accountability); ability to meet security objectives; ability to support mobile terminals, ability to utilize mobile/transportable elements based on element size and potential user impact; risk of overseas deployment associated with PSN, CSF, I-S/A AMPE(E) and size of CONUS/overseas trunks.

(2) Flexibility. This criterion measures the ability of an architecture to accommodate change. Ten subcriteria were defined in two major areas, adaptability and expandability. Adaptability refers to the ability of an architecture to accommodate changes in the demand or utilization of its planned capabilities. Expandability measures the ability of the architecture to accomodate additional requirements. The subcriteria used include: traffic type adaptability, external interface adaptability, network service adaptability, subscriber/traffic distribution adaptability, subscriber expandability, protocol expandability, service expandability, control function expandability, traffic expandability and external interface expandability. Other factors considered within these subcriteria include: the impact of changes in the amount of bulk versus narrative traffic, secure versus non-secure traffic, PSN

versus I-S/A AMPE connected subscribers, local versus remote traffic; the impact of increasing the number and types of subscribers, link protocols, user level protocols, network level protocols, and services.

(3) Survivability/Availability/Supportability. This criterion considers the inherent ability of an architecture to provide the required service in both normal and hostile operating environments. The subcriteria defined in this category include: the effect of nodal/link failures on system operation, the ability of the architecture to protect against nodal/link failures, the ability of the architecture to recover from failures and the supportability of the architecture. The factors considered within this criterion include the potential loss of service and access, the complexity of CARP (source/network), dual homing flexibility, ability to support redundant nodes, number of elements requiring support and degree of commonality among elements.

(4) Transition. This criterion considers the ability of an architecture to evolve from the near-term to and beyond the specific mid-term architecture. Subcriteria identified within this area were development risk, user impact, ease of implementation, and potential for continued evolution. The factors considered include: hardware and software development risks, continuity/disruption of service, availability of required elements, extent of modifications required to existing elements, consistency with future long-term architectural objectives (e.g., satellite broadcast backbone, integrated voice and data).

(5) Cost. This criterion measures the potential of each architecture for reducing the cost of ownership and operation of the Mid-Term IAS. Major cost elements considered as subcriteria within this category are transmission costs, nodal element acquisition cost, and operation and maintenance cost. The cost factors considered include initial and recurring costs associated with: backbone trunks and access area communications facilities, hardware and software investment costs, and personnel support and training costs.

b. Evaluation Results. Based upon the results of the evaluation process the preferred architecture for the Mid-Term IAS will be based upon Alternative II. (Also see Section III, paragraph 5 for additional comparison of the alternatives.) This alternative was determined to be preferred to each of the other alternatives in three of the five major evaluation criteria including the two technical criteria which are considered most important for the

Mid-Term IAS - transition and survivability/availability/supportability. A principal characteristic of this architecture which led to its selection is the consolidation/integration of network and user motivated functions into a single service element based upon the currently planned Inter-Service/Agency AMPE program. This consolidation/integration provides significant potential benefits in both cost and performance and contributes materially to the ease of transition from near-term to the mid-term network architecture. The preferred architecture as well as the two alternatives are described in more detail in the next section.

SECTION III

MID-TERM ARCHITECTURE

1. INTRODUCTION

The preferred architecture for the Mid-Term Integrated AUTODIN System (IAS) is based on the selection of Alternative II. This architecture meets all anticipated Mid-Term IAS operational requirements and provides a substantial improvement over the near-term. The preferred architecture provides significant advantages over other architectures in terms of transition capabilities (both for the mid-term and beyond), survivability/availability/supportability and cost.

The preferred architecture for the Mid-Term IAS is described fully in the following paragraphs. Alternative architectures are described in terms of their differences from the preferred architecture in subsequent paragraphs. This method of presentation was selected in order to reduce the unnecessary redundancy between architecture descriptions as well as to highlight the differences between architectural alternatives. The final paragraph in this section provides the summary comparison of the three architectures and the basis for recommendation of the preferred architecture.

2. DESCRIPTION OF PREFERRED ARCHITECTURE

a. Elements. The preferred Mid-Term IAS Architecture will use a combination of existing and newly developed network elements. The major elements of the architecture and their application/role in the architecture are discussed in the following subparagraphs.

(1) Packet-Switched Node (PSN). The preferred architecture will use the PSN (described in Section II, 1, c (1)) as the backbone switching element for the Mid-Term IAS. The AUTODIN II PSN will not require any anticipated modifications to fill this role. As discussed in Appendix E, the security subsystem (access control and key variable distribution) can be implemented in a separate host computer connected to the PSN via the network for ease of transition. The PSN will, therefore, not be affected by the conversion from link to end-to-end encryption. The PSN of the Mid-Term Architecture will require the TAC capability to terminate character oriented subscribers. In addition, the ability of the PSN to terminate AUTODIN I, Mode I subscribers through use of a predefined segment leader (cut-through) will be retained in the Mid-Term. No changes

are anticipated to the normal routing procedures implemented in the PSN. New contingency routing schemes will be accomplished in the preferred architecture within other network elements such as the I-S/A AMPE. For further description of the AUTODIN II PSNs, see Reference B.

(2) Inter-Service/Agency AMPE (I-S/A AMPE). The I-S/A AMPE is used in the preferred architecture as both a local message processing service element and a communications network front end. A simplified block diagram of the I-S/A AMPE is illustrated in Figure 9. As indicated, the I-S/A AMPE will include the same SIP and TCP functions contained in a PSN TAC and will function as a remote TAC to the PSN (see PSN subparagraph above). In addition, the I-S/A AMPE will include THP and terminal control functions needed to interface AUTODIN II type subscribers, as well as the store-and-forward processing functions needed to interface AUTODIN I terminals. In addition to terminating both AUTODIN I and AUTODIN II type subscribers, the I-S/A AMPE will provide the terminal support functions (PLA/RI conversion, format validation, etc.) needed to support user terminals that require such services. In order to fill its role as a network front end, the I-S/A AMPE will incorporate network protocols and processing capabilities that will permit most simple direct terminal-to-terminal/host transactions to take place without the involvement of other higher level service elements except the PSN switches. As a result of this capability, the I-S/A AMPEs will significantly contribute to more efficient use of backbone facilities and improve survivability. In its role as a network front end, the I-S/A AMPE will forward traffic from subscribers requiring higher level service to the appropriate network service elements. However, unlike the current system of dedicated "home" service elements, the I-S/A AMPE will be able to forward traffic to any element in the network capable of providing the service. This capability will allow dynamic laod balancing among the higher level elements (I-S/A AMPE(E)) in normal conditions, and provide a method of contingency recovery in the event of loss of a service element. The I-S/A AMPE will replace all current AMPEs but not necessarily on a one-for-one basis. Because of its standardized implementation/operation, the I-S/A AMPE will satisfy all service/agency requirements. This will allow consolidation of current AMPE locations with no reduction in service. Finally, the I-S/A AMPE will provide the basis for network expansion through upgrade of installed I-S/A AMPEs to enhanced I-S/A AMPE(E) configurations. Based on a modular transportable software development approach, it is anticipated that any I-S/A AMPE can be converted to enhanced status after installation. The I-S/A AMPE family of equipments is, therefore, the key to both implementation and continued evolution/growth of the IAS network.

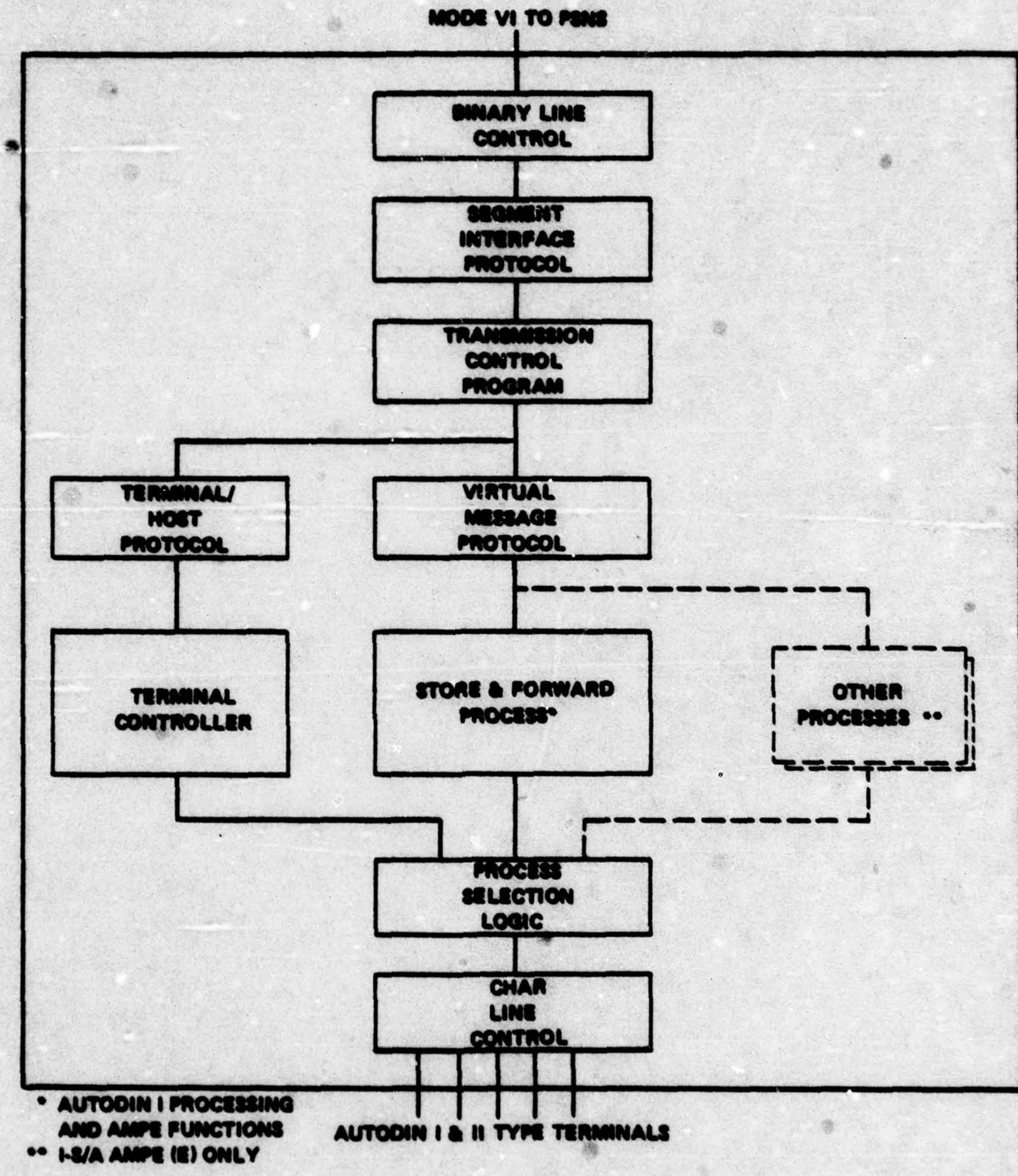


Figure 9. Inter-Service/Agency AMPE

(3) Enhanced Inter-Service/Agency AMPE (I-S/A AMPE(E)). In the preferred architecture, the I-S/A AMPE(E) will fill two distinct roles. First, it will function as a normal I-S/A AMPE for its locally connected subscribers. In this role it will provide local terminal support and message processing functions and act as the network front end. Secondly, the I-S/A AMPE(E) will serve as a network service element. In this role the I-S/A AMPE(E) will provide network services to both locally connected and remote access subscribers throughout the network. As a network service element, the I-S/A AMPE(E) will support/augment the capability of the lower level I-S/A AMPE and terminal elements by performing message/data processing services that require processing and/or data storage capacity beyond that available in the lower level elements. Typical services in this category include: special code/format conversion; message exchange with systems outside IAS; mailbox storage; file storage, update, and retrieval; telecommunications conference control and record keeping. Shared network use of these I-S/A AMPE(E) capabilities will significantly reduce the processing and storage requirement of the I-S/A AMPE and terminal equipments. This in turn should significantly reduce the total network acquisition and operating cost to provide a given level of network service. The I-S/A AMPE(E) will be developed under the same program as the I-S/A AMPE and will share its basic software modules. The block diagram contained in Figure 9, therefore, is also applicable to the I-S/A AMPE(E). The I-S/A AMPE(E) will, of course, include additional software modules, additional hardware processing and storage capacity, and additional communications interface hardware/software As indicated previously, the I-S/A AMPE(E) installations will in many cases be accomplished by retrofit/upgrade of previously installed I-S/A AMPEs.

(4) Subscriber Terminals. As previously stated, it is expected that the Mid-Term IAS will have to support all existing types of AUTODIN I and planned AUTODIN II terminals. It is also expected that terminals with additional capabilities will be introduced in the Mid-Term as part of the Common Family of AUTODIN Terminals. Although increased capability in some terminals will not relieve the network of supporting the remainder of less capable terminals, it can reduce the processing load on the network and reduce the dependence of the terminals on other network elements. A summary of anticipated Mid-Term subscriber terminal characteristics is shown in Table IV.

b. Configuration/Connectivity. The basic configuration of network elements in the preferred architecture is illustrated in Figure 10. Figure 11 illustrates all generic single

TABLE IV. ANTICIPATED MID-TERM IAS TERMINAL CHARACTERISTICS

TYPES - All AUTODIN I and AUTODIN II types plus common family of terminals to include more intelligent/capable terminals

PROTOCOLS - All AUTODIN I and AUTODIN II protocols plus additional unique link protocols (e.g., AMPE user protocols) and new end-to-end protocols (e.g., Virtual Message Protocol) I-S/A AMPE-to-I-S/A AMPE

CODES - ASCII and ITA#2 (others transparent)

SPEEDS - 45.5 - 56k bps

FORMATS - AUTODIN II Segment Formats, JANAP 128, ACP 126/127, DOI 100/103, DD-173

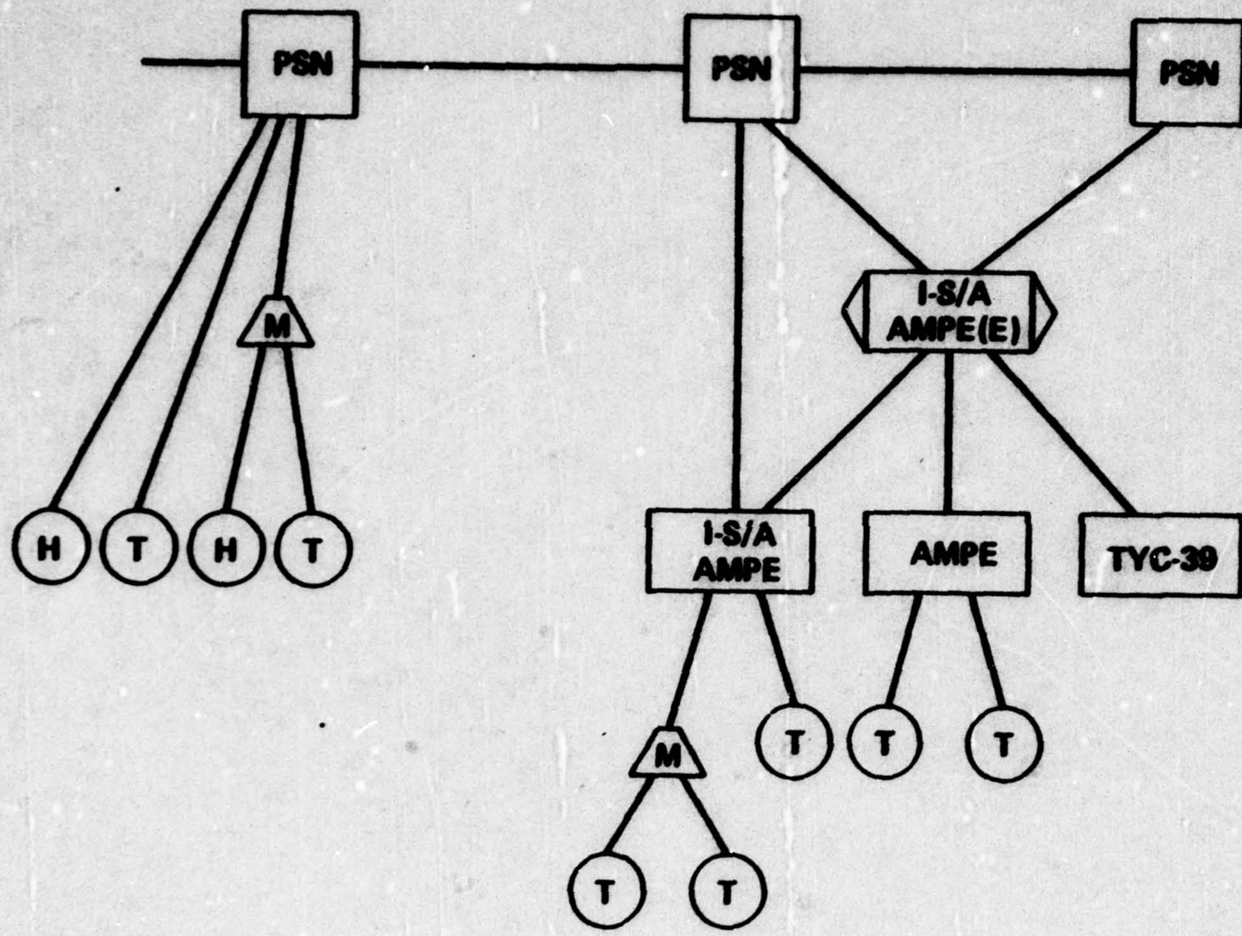
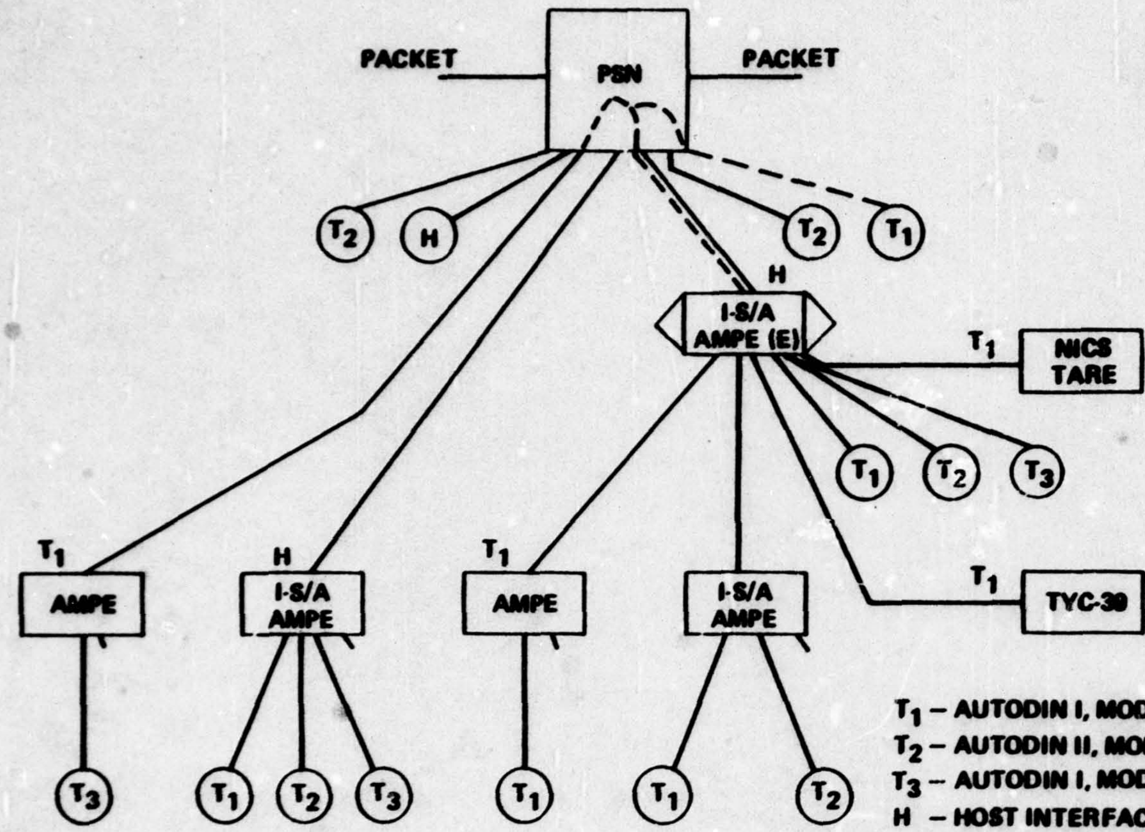


Figure 10. Preferred Architecture Configuration



T_1 – AUTODIN I, MODE I
T_2 – AUTODIN II, MODE I, IB, IIA, VI
T_3 – AUTODIN I, MODE II, V OR USER UNIQUE*
H – HOST INTERFACE MODE VI, BSL
– – REMOTE HOMING VIA "CUT THROUGH"

* NOT ALL MODES AT ALL NODES

Figure 11. Preferred Architecture Connectivity

connections (both preferred and alternative) between elements in more detail. As indicated in this diagram, AUTODIN I type subscribers (including AMPEs) connected to PSNs will enter messages in AUTODIN I formats via the PSN TAC and all of their traffic will be automatically routed (cut-through) to a designated I-S/A AMPE(E) for processing. Since the PSNs do not process the AUTODIN I Header containing precedence and security format elements, all cut-through traffic will be handled at the highest level precedence and security. For this reason, direct connection of AUTODIN I type subscribers to I-S/A AMPEs or I-S/A AMPE(E)s is preferred to PSN connection. Although not shown in Figure 11, terminals may be homed either singly or dually to any combination of the nodal element types, i.e., PSN, I-S/A AMPE(E), or I-S/A AMPE.

I-S/A AMPEs may be connected to PSNs or I-S/A AMPE(E)s and can be dual connected to one or both of those element types. As discussed previously, I-S/A AMPEs may exchange message traffic without routing it through an I-S/A AMPE(E). Since some I-S/A AMPE traffic will require routing to an I-S/A AMPE(E) for service and some will be routed directly through the PSN backbone, the preferred connectivity for an I-S/A AMPE will be dual connection to both a PSN and an I-S/A AMPE(E). Depending on the specific communities of interest served by an I-S/A AMPE and the proportions of traffic types, it will be possible to connect (singly or dually) an I-S/A AMPE to either one of those element types.

I-S/A AMPE(E)s will access the network directly via a PSN. They will normally be dual connected to PSNs for survivability.

Tactical and allied system interfaces in AUTODIN I subscriber modes will have the same connection options as AUTODIN terminals, and for the same reasons, connection of AN/TYC-39 and NICS TARE relays to an I-S/A AMPE or I-S/A AMPE(E) is preferred. The interface between I-S/A AMPE and I-S/A AMPE(E)s will be Mode VI.

I-S/A AMPEs will not normally be directly interconnected, but for contingencies may connect using Mode I or Mode VI protocol. The interconnectivity of all network elements is summarized in Figure 12.

The connectivity options offered by the architecture allow flexibility for overseas deployment. In general, the backbone IAS network will be extended by locating PSNs overseas. For transition purposes, however, the required services can also be provided to

FROM \ TO	PSN	I-S/A AMPE(E)	I-S/A AMPE	AMPE	HOST	TERMINAL
PSN	BACKBONE NETWORK	CONNECTED TO MULTIPLE I-S/A AMPE(E)	CONNECTED TO MULTIPLE I-S/A AMPEs	*†CONNECTED TO MULTIPLE AMPEs	CONNECTED TO MULTIPLE HOSTS	CONNECTED TO MULTIPLE TERMINALS
I-S/A AMPE(E)	DUAL CONNECTED	*	CONNECTED TO MULTIPLE I-S/A AMPEs	CONNECTED TO MULTIPLE AMPEs	NA	CONNECTED TO MULTIPLE TERMINALS
I-S/A AMPE	SINGLE OR DUAL	SINGLE OR DUAL	*	CONNECTED TO MULTIPLE AMPEs	NA	CONNECTED TO MULTIPLE TERMINALS
AMPE	†*NORMALLY SINGLE, OPTIONALLY DUAL	NORMALLY SINGLE, OPTIONALLY DUAL	NORMALLY SINGLE, OPTIONALLY DUAL	NA	NA	CONNECTED TO MULTIPLE TERMINALS
HOST	SINGLE OR DUAL	NA	NA	NA	NA	CONNECTED TO MULTIPLE ADP STATIONS
TERMINAL	NORMALLY SINGLE, OPTIONALLY DUAL	NORMALLY SINGLE, OPTIONALLY DUAL	NORMALLY SINGLE, OPTIONALLY DUAL	NORMALLY SINGLE, OPTIONALLY DUAL	NORMALLY SINGLE, OPTIONALLY DUAL	NA

* THESE CONNECTIONS WILL BE CONSIDERED ON A CASE-BY-CASE BASIS.
† CONNECTED FOR TERMINATION ONLY. SERVICES ARE PROVIDED BY OTHER ELEMENTS.
NA NOT APPLICABLE.

Figure 12. Preferred Architecture Connection Policy

overseas users before deploying PSNs overseas by connecting overseas I-S/A AMPEs and/or I-S/A AMPE(E)s directly to conus PSNs. Alternatives for overseas implementation are further discussed in Section IV, TRANSITION.

c. Protocols. The implementation of the preferred Mid-Term Architecture will require the development of at least one new network level protocol. This protocol, called the Virtual Message Protocol (VMP) will support direct exchange of message information among I-S/A AMPEs and between I-S/A AMPEs and I-S/A AMPE(E)s connected via the PSN backbone. Additional network level and link level protocols may be identified in the process of further defining the Mid-Term network services and operating procedures. However, these new protocols will be implemented only in the new IAS Mid-Term elements. No new protocols are required in existing elements to support the preferred architecture. This is a significant consideration in the evolutionary development of the Mid-Term IAS network.

The anticipated link and network level protocols and their use in the preferred architecture are discussed further in the following subparagraphs.

(1) Link Protocols. The link level protocols anticipated between Mid-Term elements are summarized in Figure 13.

(2) Network Level Protocols. The Mid-Term Architecture makes use of the protocol layers defined for AUTODIN II. The new IAS elements, the I-S/A AMPE and I-S/A AMPE(E), will operate through the network using host-type protocols, i.e., they will employ the Segment Interface Protocol (SIP) and Transmission Control Program (TCP) defined in Reference B. In addition, they will use a Virtual Message Protocol (VMP) for exchanging message traffic through the packet network. The VMP will include functions necessary for routing and accountability of narrative/record traffic (most of which are presently provided by the ASCs), such as message acknowledgements, rejections, cancellations, service message generation, and message control block functions. The network level protocols required by the Mid-Term IAS Architecture are defined in the following subparagraphs.

Switch-to-Switch Protocols. Switch-to-Switch protocols are defined for AUTODIN II PSNs to accomplish routing, accountability and flow control between local and source/destination packet switches. These protocols are not changed by the Mid-Term Architecture.

NETWORK ELEMENTS	PSN	I-S/A AMPE(E)	I-S/A AMPE	AMPE	HOST	TERMINAL
PSN	VI	VI	VI	*I	VI	I, IB, IIA, VI
I-S/A AMPE(E)	VI	*VI	VI	I	NA	**I, IB, II, IIA, V, VI, SS
I-S/A AMPE	VI	VI	*VI	I	NA	**I, IB, II, IA V, VI, SS
AMPE	*I	I	I	NA	NA	**I, II, V, SS
HOST	VI	NA	NA	NA	NA	HS
TERMINAL	I, IB IIA, VI	**I, IB, II, IIA V, VI, SS	**I, IB, II, IIA, V, VI, SS	**I, IB, II, IIA, V, SS	NA	NA

* THESE CONNECTIONS WILL BE CONSIDERED ON A CASE-BY-CASE BASIS.
** ALL AMPES DO NOT HAVE ALL MODES.

NA – NOT APPLICABLE
I – AUTODIN I MODE I, CHARACTER SYNCHRONOUS
IB – AUTODIN II MODE IB, CHARACTER SYNCHRONOUS
II – AUTODIN I MODE II, CHARACTER ASYNCHRONOUS (UNCONTROLLED)
IIA – AUTODIN II MODE II, CHARACTER ASYNCHRONOUS
V – AUTODIN I MODE V, CHARACTER ASYNCHRONOUS (CONTROLLED)
VI – AUTODIN II MODE VI, BINARY SYNCHRONOUS
HS – HOST SPECIFIED
SS – SUBSCRIBER SPECIFIED

Figure 13. Preferred Architecture Link Protocols

Host-to-Switch Protocol. The protocol used between PSNs and AUTODIN II hosts and between PSNs and I-S/A AMPEs and I-S/A AMPE(E)s is the Segment Interface Protocol (SIP), accomplished through the exchange of binary segment leaders.

Host-to-Host Protocols. Host-to-Host protocols refer to the general set of protocols used between host computers or automated message exchanges communicating through the network. They include the Transmission Control Protocol (TCP) and other host-specific protocols. The I-S/A AMPEs and I-S/A AMPE(E)s will use the TCP for communicating through the network with host computers, other I-S/A AMPEs and I-S/A AMPE(E)s, and PSN Terminal Access Controllers (TAC). In addition, the I-S/A AMPEs will use the new Virtual Message Protocol (VMP) for exchanging narrative/record traffic among themselves and with other hosts or automated message processing facilities which employ the VMP protocol.

Terminal-to-Host Protocols. Terminal-to-Host protocols refer to the general set of protocols which allow terminals to interact with hosts or message processing elements. The standard AUTODIN II Terminal-to-Host Protocol (THP) will be used in the Mid-Term Architecture for this purpose. The THP supports terminal-to-terminal and terminal-to-process transactions by making the various terminals and processes appear as similar as possible to users. These transactions require interaction between source and destination THPs and between the THPs and the terminals and host processes. In AUTODIN II, the THP is implemented in host computers and PSN TACs. Since the I-S/A AMPEs and the I-S/A AMPE(E)s will provide a TAC capability for AUTODIN II type subscribers, they will also implement the THP. The elements which directly terminate subscribers must also incorporate terminal handlers, or terminal control protocols tailored to the characteristics of the specific terminals.

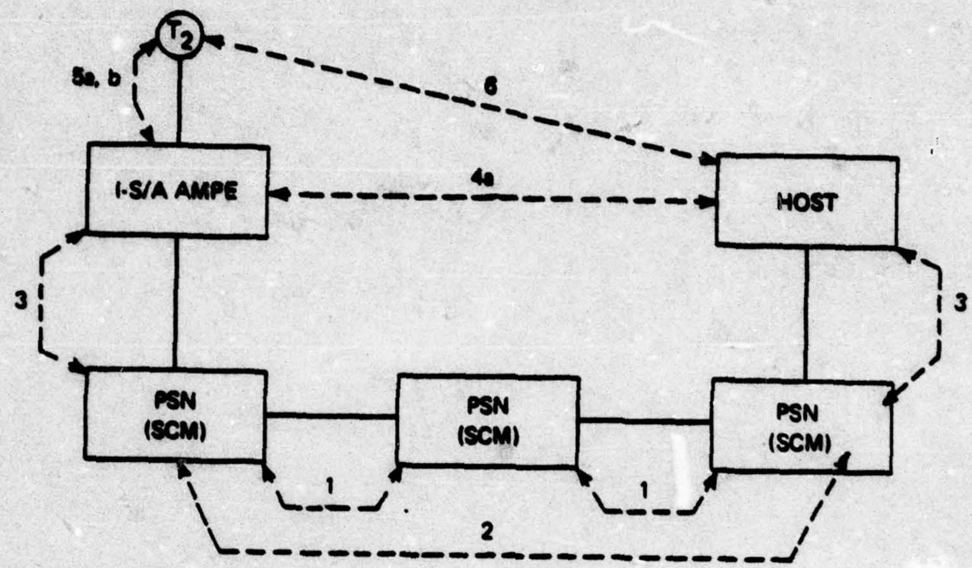
User-to-User Protocols. User-to-user protocols are the procedures effected between end users of the network (where the end users may be terminal/system operators or software processes) through exchange of control information and message format. The packet switch network and the protocol levels described above are transparent to the user-to-user protocols. User-to-user protocol includes such functions as user interaction with a host software process and end-to-end security functions. Message format instructions for message distribution and handling by I-S/A AMPEs, I-S/A AMPE(E)s, AMPEs, and terminals, such as transmission control/release codes, office symbols, flagwords or references are also considered within the class of user-to-user protocols for the purposes of this protocol definition.

Figures 14 and 15 show examples of the application of the classes of protocols described above. Figure 14 shows the primary layers of protocols required for a transaction between an I-S/A AMPE connected AUTODIN II type terminal and a PSN connected host computer. (Additional protocol layers exist which are not shown in this and other diagrams, such as originating terminal to destination host and originating host to destination PSN. Also not shown are link level protocols.) In this example, the TAC equivalent functions in the I-S/A AMPE provide host level protocols.

Figure 15 shows the network protocols for an AUTODIN I type transaction between I-S/A AMPE or I-S/A AMPE(E) connected subscribers. In this case the Virtual Message Protocol (VMP) is employed between the I-S/A AMPEs or I-S/A AMPE(E)s to control the exchange of narrative/record messages through the network. A user-to-user level protocol is shown between the I-S/A AMPEs or I-S/A AMPE(E)s which includes message format processing such as distribution instructions. The THP used for AUTODIN II type transactions does not apply in this case.

d. Functional Allocation. The allocation of functions to network elements in the preferred architecture is summarized in Figure 16. In order to illustrate the evolutionary transition required from the near-term to the mid-term, Figure 16 includes the current near-term AUTODIN elements and illustrates their functional capabilities. As noted in Section II, the functions required for the basic AUTODIN I narrative/record message transfer service can be generally categorized as subscriber support functions (e.g., code and format conversion, message retrieval) and network functions (e.g., multiple/collective routing). In the preferred architecture, the subscriber support functions are allocated to the I-S/A AMPE because they are most effectively performed at a point near the subscribers, and because many of these functions are already performed in the existing AMPEs. In addition, the I-S/A AMPE is also assigned the AUTODIN II terminal access functions and a Mode VI host-type interface to the PSN both to provide flexibility for subscriber termination to the network, and to ensure an efficient, potentially high speed, network access. In this architecture, the AUTODIN I network (ASC replacement) functions as well as the functions required to support new IAS services are allocated to the I-S/A AMPE(E). Since the I-S/A AMPE(E) is a modular enhancement of the I-S/A AMPE, it also has all the capabilities of the I-S/A AMPE.

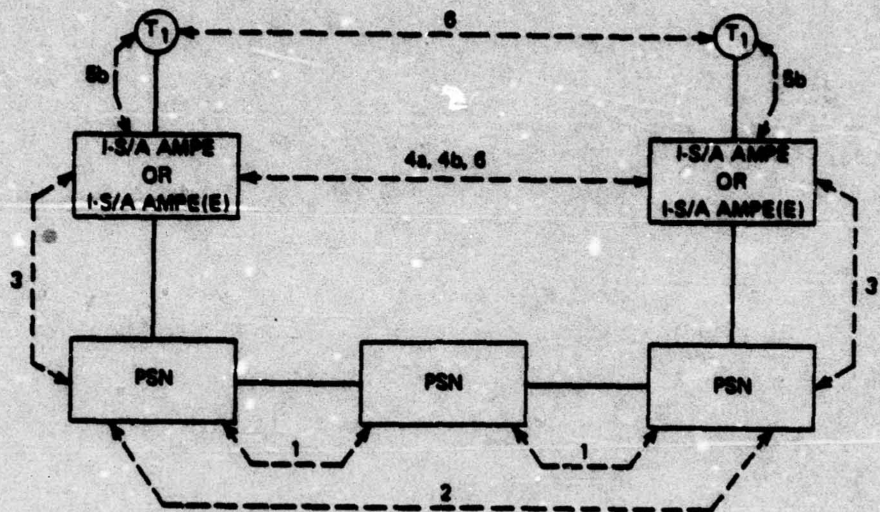
During the mid-term, the IAS Architecture must support both link encrypted and end-to-end encrypted users. For link encrypted



1. SWITCH/SWITCH (LOCAL)
2. SOURCE SWITCH/DESTINATION SWITCH
3. HOST/SWITCH (SIP)
4. HOST/HOST
   a. TCP
   b. VMP
5. TERMINAL/HOST
   a. THP
   b. TERMINAL CONTROL
6. USER/USER

T_2 – AUTODIN II TERMINAL

Figure 14. IAS Network Protocols, Terminal/Host Transaction



1. SWITCH/SWITCH (LOCAL)
2. SOURCE SWITCH/DESTINATION SWITCH
3. HOST/SWITCH (SIP)
4. HOST/HOST
   a. TCP
   b. VMP
5. TERMINAL/HOST
   a. THP
   b. TERMINAL CONTROL
6. USER/USER

T_1 – AUTODIN I TYPE TERMINAL

Figure 15. IAS Network Protocols, Terminal/Terminal Transaction

FUNCTION	EXISTING NEAR TERM ELEMENTS				NEW END TERM ELEMENTS		
	ASC	PSN	AMPE	TERMINALS	I-S/A AMPE	I-S/A AMPE (E)	TERMINALS
MESSAGE SWITCHING							
HEADER VALIDATION	●		●	○	▲	▲	△
PRECEDENCE QUEUING/PRE-EMPTION	●		●	○	▲	▲	△
ROUTING (SINGLE ADDRESS)	●		●	○	▲	▲	
ALTERNATE ROUTING: LOCAL	●		●		▲	▲	
REMOTE (CARP)	●					▲	
MULTIPLE/COLLECTIVE: MULTIPLE TRANSMISSIONS/LINE	●		○			▲	
SINGLE TRANSMISSION/LINE	●		●		▲	▲	
ROUTING LINE SEGREGATION	●		●		▲	▲	
TRC/SPECAT PROCESSING	●		○		▲	▲	
MCB FUNCTIONS	●				▲	▲	
PACKET SWITCHING							
LEADER/HEADER CONVERSION		●					
LEADER/HEADER VALIDATION		●		○	▲	▲	△
ROUTING		●					
CONCENTRATION (MULTIPLE ENTRY)				○	▲	▲	△
ADAPTIVE ROUTING		●					
PRECEDENCE QUEUING		●		○	▲	▲	△
LOOPING CONTROL		●					
COLLECTION/DISTRIBUTION							
DISTRIBUTION BY: LOGICAL ADDRESS					▲	▲	◆
PLA			●	○	▲	▲	△
FORMAT ELEMENT (SUBJECT, AIG, ETC.)			●	○	▲	▲	△
CONTENT ADDRESSING			●		▲	▲	◆
FORMAT PROCESSING							
JANAP - 128	●		●	○	▲	▲	△
ACP - 127	●		●	○	▲	▲	△
ACP - 126	●		○	○	▲	▲	△
DOI - 103	●		○	○	▲	▲	△
DOI - 10[illegible]	●		○	○	▲	▲	△
DD - 173			○	○	▲	▲	△
CONVERSION FUNCTIONS							
MESSAGE FORMAT: JANAP 128/ACP 127	●		○	○	▲	▲	△
DD 173/JANAP 128, 127			●	○	▲	▲	△
MEDIA FORMAT (CARD, TAPE, ETC.)	●		●	○	▲	▲	△
PLA, RI/LOGICAL ADDRESS	○				▲	▲	◆
PLA/RI	●		●	○	▲	▲	△
SPEED	●		●		▲	▲	
CODE	●		●	○	▲	▲	△
PROTOCOLS							
HOST-TO-NODE	●	●		○	▲	▲	△
NODE-TO-NODE		●					
HOST-TO-HOST	●			○	▲	▲	△
LINK - AUTODIN I, MODE: I	●	●	●	○	▲	▲	△
II	●		●	○	▲	▲	△
V	●		○	○	▲	▲	△
AUTODIN II, MODE: I		●		○	▲	▲	△
I B		●		○	▲	▲	△
II A		●		○	▲	▲	△
VI	●	●		○	▲	▲	△
AMPE UNIQUE			●	○	▲	▲	
MESSAGE/FILE STORAGE & RETRIEVAL							
STORE OFF-LINE FOR RETRIEVAL	●		●	○	▲	▲	△
STORE ON-LINE FOR RETRIEVAL	●		●	○	▲	▲	△
INTERCEPT STORAGE	●		●		▲	▲	
EDIT MESSAGES ON FILE			○	○	▲	▲	△
READDRESS MESSAGES ON FILE			○	○	▲	▲	△
STORE STANDARD FORMS			○	○	▲	▲	△
MESSAGE/FILE ACCESS CONTROL	●		●	○	▲	▲	△
RETRIEVE BY: MESSAGE ID	●		●	○	▲	▲	△
ADDRESSEE	●		●	○	▲	▲	△
TIME OF RECEIPT	●		●	○	▲	▲	△
CODE WORD			●	○	▲	▲	△
SYSTEM MANAGEMENT & CONTROL							
JOURNALING/LOGGING	●		●	○	▲	▲	△
MESSAGE RECOVERY RETRIEVAL	●		●	○	▲	▲	△
SERVICE MESSAGE GENERATION	●		●		▲	▲	
FLOW CONTROL		●		○	▲	▲	△
STATISTICS GENERATION	●	●	●	○	▲	▲	△
BILLING		●			▲	▲	
STATUS MONITORING	●	●	●	○	▲	▲	△
MESSAGE TRACE	●	●	●		▲	▲	
USER INTERFACE							
I/O MEDIA/SYSTEM CONVERSIONS:				○			△
FORMAT & CODE				○			△
SIGNAL				○			△
BUFFERING				○			△
MESSAGE HEADER ENTRY				○			△
SEGMENT LEADER ENTRY		●		○	▲	▲	△
EDITING		●			▲	▲	
ECHO		●			▲	▲	
CONNECTION CONTROL		●			▲	▲	
SECURITY							
ENCRYPTION/DECRYPTION	●	●	●	○	▲	▲	△
AUTOMATIC KEY VARIABLE DISTRIBUTION		●				●	
ACCESS CONTROL		●				●	
USER AUTHENTICATION		●				●	
SP/TCC VALIDATION	●	●	●	○	▲	▲	△
SECURITY TRACE AND AUDIT		●				●	
DATA AUTHENTICATION	●	●	●	○	▲	▲	△
TRAFFIC FLOW SECURITY	●	●	●	○	▲	▲	△

● - PRESENTLY PERFORMED BY INDICATED ELEMENTS
○ - PRESENTLY PERFORMED BY SOME TYPES OF THE INDICATED ELEMENT
▲ - ALLOCATED TO INDICATED ELEMENT IN THIS ARCHITECTURE
△ - ALLOCATED TO SOME TYPES OF INDICATED ELEMENTS IN THIS ARCHITECTURE
◆ - OPTIONAL ALLOCATION, TO BE DETERMINED

Figure 16. Preferred Architecture Functional Allocation

users the I-S/A AMPE and I-S/A AMPE(E) in the preferred architecture will provide encryption and decryption functions and the security processing functions of format and input/output line validation. There are several options for the allocation of end-to-end security functions in the preferred architecture, including their allocation to the I-S/A AMPE(E) or PSN. These options are discussed in Appendix E.

As previously discussed, the Mid-Term Architecture will have to support the range of existing AUTODIN I and AUTODIN II user terminals, including unintelligent terminals. Although these terminals will exist throughout the mid-term, a new standard family of AUTODIN terminals with additional capabilities is planned for development for use in the Mid-Term. The analysis and evaluation of architectures performed as part of the IAS definition revealed several major functions that should be considered for implementation within the range of future terminals. Some of the major functions identified are:

- o Generation of network logical addresses and conversion between logical addresses, plain language addresses and routing indicators
- o Recognition and appropriate addressing of traffic that requires processing by a service element
- o Performance of end-to-end terminal security functions
- o Conversion of user unique formats to common network formats
- o Automatic message preparation assistance (prompting, editing, etc.)
- o Automatic message distribution
- o Direct interface with PSNs using Mode VI host-type protocols and Virtual Message Protocol

The anticipated results of performing these functions in terminals vice other elements would be to relieve the network of local processing requirements, reduce the dependence of the terminals on other network elements (i.e., to facilitate mobility/survivability) and to improve the response time of the user-to-network interface.

e. Network Services. Section II-4.e describes the candidate network services currently defined for the Mid-Term IAS. Any or all of these services can be provided by the Mid-Term IAS Architecture as required. Implementation of certain of these services may require changes to, or development of, policies, standards, and procedures to facilitate their use. The following subparagraphs illustrate how these services would be implemented in the preferred architecture.

(1) Narrative/Record Message Transfer. Subscribers connected to I-S/A AMPEs or I-S/A AMPE(E)s will receive this service directly from those elements. Since the I-S/A AMPE(E) will have more capability than the I-S/A AMPE, subscriber traffic requiring special processing will be forwarded from the I-S/A AMPE to the I-S/A AMPE(E) for additional narrative/record service. All traffic from subscribers directly connected to PSNs and operating in AUTODIN I modes will be "cut-through" to an I-S/A AMPE(E) for processing (AMPEs will normally be directly connected to an I-S/A AMPE(E) but may be "cut-through" to an I-S/A AMPE(E) via a PSN). Subscribers connected to PSNs and operating in AUTODIN II modes will have access to Narrative/Record Message Transfer service only when an I-S/A AMPE subscriber is the addressee. Otherwise their traffic will be handled by the PSN network as ADP transactions. In-transit and history message storage will be provided by the I-S/A AMPEs and I-S/A AMPE(E)s. PSNs provide only in-transit packet storage.

(2) Narrative/Record Message File Retrieval. Narrative/record messages passing through I-S/A AMPEs and I-S/A AMPE(E)s will be stored for a prescribed period of time. Other data such as standard forms may also be stored in these elements by a user on request for later recall. The I-S/A AMPE(E) will also provide a storage and retrieval service for other users (i.e., PSN-connected subscribers) who can store and retrieve data by addressing the I-S/A AMPE(E).

(3) ADP Transaction Transfer. The PSNs are designed to handle ADP transactions for hosts and subscriber terminals. The service will also be provided to I-S/A AMPE and I-S/A AMPE(E) subscribers via the TAC function provided in those elements. All ADP transactions generated by I-S/A AMPE and I-S/A AMPE(E) subscribers will be forwarded to a PSN for routing.

(4) Privacy Service. This service will be available to I-S/A AMPE or I-S/A AMPE(E) connected subscribers. It is a reduction in the normal narrative/record transfer service only in that the I-S/A AMPE and I-S/A AMPE(E) will not retain storage of messages for retrieval or history. Journals will be maintained.

(5) Informal Message Exchange. This service is available to PSN, I-S/A AMPE, and I-S/A AMPE(E) connected subscribers. This type of message bypasses the normal narrative/record format verification and controls in the I-S/A AMPEs and I-S/A AMPE(E)s. The service is inherently available between PSN-connected subscribers since the PSNs do not process message formats.

(6) Mailbox Service. Regardless of source, Mailbox messages will be routed to an I-S/A AMPE(E) which will make the appropriate distribution of the messages to mailboxes located in other I-S/A AMPE(E)s throughout the network. Subscribers connected to an I-S/A AMPE(E) will have their mailbox traffic distributed by the connected I-S/A AMPE(E). For terminals connected to an I-S/A AMPE, the I-S/A AMPE will recognize mailbox transactions and forward them to a designated I-S/A AMPE(E) for distribution to mailboxes. Subscribers connected to PSNs must address their mailbox traffic to an I-S/A AMPE(E) since the PSN will not have the capability of distinguishing between mailbox transactions and other transactions. The I-S/A AMPE(E) will store mailbox traffic for designated users and will:

- o Respond to inquiries from the users requesting information concerning their mailbox (e.g., number of messages in the mailbox and their time of arrival)
- o Control access to mailboxes
- o Deliver mailbox messages to the users upon request
- o Remove mailbox traffic from the system, after notifying the originator and addressee, if not retrieved within a specific time.

Mailbox service is an augmentation to the informal message exchange service.

(7) Data Teleconferencing. In the preferred architecture, an I-S/A AMPE(E) controls the conference, stores conference transactions and responds to requests for conference data or status information from the members. The data teleconference service is available to subscribers connected to PSNs, I-S/A AMPEs and I-S/A AMPE(E)s. I-S/A AMPEs will recognize teleconference transactions and forward them to an I-S/A AMPE(E) for processing, but subscribers connected to PSNs will have to address the transactions to an I-S/A AMPE(E). A user may establish a conference by sending a request including identification of the desired members to an I-S/A AMPE(E).

The I-S/A AMPE(E) will notify the members and provide them with the addressing information necessary to address the conference or retrieve conference data or status information. All conference transactions will flow through the I-S/A AMPE(E) controlling the conference. When members are signed onto a conference, they will automatically receive all transactions addressed to the conference or to them individually. The I-S/A AMPE(E) will store a transcript of the conference so that members signing on to the conference may retrieve prior conference entries.

f. Traffic Flow. The flow of traffic through the network in the preferred architecture is described in the following subparagraphs for different types of traffic originated by subscribers connected to each of the major network elements. There are two basic types of subscribers expected in the Mid-Term IAS. The first type of subscriber may have terminal equipment (including AMPE) which will support only AUTODIN I operation or may not have sufficient need for new services to implement the necessary changes in operational procedures. The second type of subscriber expected in the Mid-Term IAS is an ADP, or AUTODIN II-type, subscriber. In the following discussion these subscribers are referred to as AUTODIN I - type and AUTODIN II - type respectively. Either type may be connected to an I-S/A AMPE(E), I-S/A AMPE or PSN.

(1) I-S/A AMPE(E) Connected Subscribers. Traffic submitted to the I-S/A AMPE(E) from AUTODIN I - type subscribers will be addressed with Plain Language Addresses (PLAs) or Routing Indicators (RIs) and may be in any one of the AUTODIN I formats (JANAP 128, ACP-126/127, DOI-103, DD 173). This traffic will be automatically transferred to the store-and-forward message processing portion of the I-S/A AMPE(E) where AMPE and AUTODIN I type functions are performed (see 2,a,(2) - Figure 9). Local distribution to directly connected subscribers (including allied/tactical) will be made directly from the I-S/A AMPE(E) as required, and network Logical Addresses (LA) will be determined for remote addressees. The I-S/A AMPE(E) will segment and forward the messages, through the PSN network, to the destination I-S/A AMPE(E), I-S/A AMPE or PSN - connected subscriber. As part of the Virtual Message Protocol, the originating I-S/A AMPE(E) will provide information to the destination I-S/A AMPE or I-S/A AMPE(E) concerning the origination code and format, to allow necessary conversions to be made for the destination subscriber and provide for message servicing actions. PSN - connected subscribers that are cut-though to the originating I-S/A AMPE(E) will be treated as local subscribers by that I-S/A AMPE(E).

Transition logs, histories and retrieval storage will be maintained at the I-S/A AMPE(E) and I-S/A AMPE unless the originating subscriber is designated/authorized for limited privacy service, in which case no permanent storage of the message is maintained.

AUTODIN II - type subscribers connected to an I-S/A AMPE(E) may enter traffic in any one of the AUTODIN I formats or in AUTODIN II format. The traffic entered in AUTODIN I format will be addressed using PLA or RI. It will be forwarded to the store-and-forward portions of the I-S/A AMPE(E) and handled as described above.

Traffic entered in AUTODIN II format will provide segment leader information, including network LA with each transaction, and the text will be free format, i.e., the message format may be one of the AUTODIN I formats or other user-to-user format. For ADP transaction transfers requiring no additional processing, the I-S/A AMPE(E) segments the traffic and forwards it to a PSN for routing. No local routing is done for this type of traffic by the I-S/A AMPE(E).

Transactions requiring processing by the I-S/A AMPE(E) for Informal Message Exchange, Mailbox Service or Data Teleconferencing will be identified by leader information. Mailbox transactions include posting of messages and retrieval of mail or status information. Teleconference transactions include establishing a conference or requesting conference status/transactions. Informal message exchange transactions, other than mailbox and teleconferencing, can be forwarded to a PSN without further processing by the I-S/A AMPE(E), but may require special handling such as multiple addressing.

(2) I-S/A AMPE Connected Subscribers. Traffic entered to an I-S/A AMPE from AUTODIN I - type subscribers will be formatted in an AUTODIN I format and addressed with RI or PLA. It will be automatically transferred to the store-and-forward portion of the I-S/A AMPE where AMPE and AUTODIN I - type functions are performed. If the message requires services not provided by the I-S/A AMPE, it will be forwarded to a directly connected I-S/A AMPE(E) or through the PSN network to a remote I-S/A AMPE(E). If no I-S/A AMPE(E) services are required the message will be distributed locally as necessary and/or forwarded through the PSN network to the destination I-S/A AMPE(E), I-S/A AMPE or PSN-connected subscriber. The VMP protocol used by the I-S/A AMPE for exchange of messages with other I-S/A AMPEs and I-S/A AMPE(E)s will allow the transfer of information concerning the origin of the message and processing required.

Traffic entered by AUTODIN II - type subscribers will be in AUTODIN I or AUTODIN II format. The AUTODIN I format messages will be transferred to the store-and-forward portion of the I-S/A AMPE and processed as described above. For AUTODIN II format transactions, the I-S/A AMPE will perform PSN TAC equivalent functions, segment the data, and forward it to the PSN. If the I-S/A AMPE is not directly connected to a PSN, this traffic is forwarded to a directly connected I-S/A AMPE(E). At the present time, procedures for separating traffic intended for I-S/A AMPE(E) processing versus relay to the PSN by the I-S/A AMPE(E) have not been defined. However, this could be accomplished through recognition of LA by the I-S/A AMPE(E) as part of a SIP-to-SIP transfer, by transmission of the two traffic types from the I-S/A AMPE via two separate logical or physical channels.

The I-S/A AMPE will recognize, via segment leader designators, transactions that require services provided only by an I-S/A AMPE(E), such as mailbox or teleconferencing, and will forward the transaction to an I-S/A AMPE(E) by inserting a segment leader with the I-S/A AMPE(E) LA. Otherwise, segments will be relayed through the I-S/A AMPE(E) containing only the destination LA.

(3) PSN-Connected Subscribers. AUTODIN I - type subscribers connected to PSNs will be automatically cut-through to a designated I-S/A AMPE(E). All traffic generated by these subscribers will be automatically routed to the I-S/A AMPE(E) which will process the traffic as if it came from a local AUTODIN I -type subscriber.

Traffic generated by AUTODIN II - type subscribers connected to PSNs must be in AUTODIN II format with segment leader information provided. Transactions which require I-S/A AMPE(E) services must be addressed to an I-S/A AMPE(E) since the PSNs will not recognize the need for such services.

g. Security. The Security Subsystem for the preferred IAS Mid-Term Architecture must provide the capability to support both end-to-end encrypted (E3) users and link encrypted users. It is expected that this mix of E3 and non-E3 users will persist throughout the mid-term and well into the far-term.

The non-E3 users will be provided security service through the use of conventional link encryption techniques such as those employed in AUTODIN I and AUTODIN II. Non-E3 users will be supported by a variety of link encryption devices such as the KG-13, KG-34, and KG-84. Non-E3 users will be afforded end-to-end security in the Mid-Term IAS through a combination of link encryption and security

kernels, or other certified techniques, used in the IAS network elements. These users will also be provided with traffic flow security (TFS) protection through the inherent TFS features of the link key generators employed for encryption/decryption. This class of user, however, will not be provided with automatic access control, user authentication, or on-line key distribution.

The E3 users will be provided service through the application of BLACKER hardware and supporting security software integrated into the various system elements of the IAS. The allocation of BLACKER components to the IAS elements is discussed in a separate classified Appendix. E3 subscribers must be capable of accessing network services (e.g., message processing, mailbox, teleconferencing) as well as other E3 subscribers. Furthermore, E3 subscribers and non-E3 subscribers must be able to access each other. The E3 operational scenarios include three generic types of connections:

- o Terminal-to-terminal
- o Terminal-to-host
- o Host-to-host

Descriptions of several operational scenarios are presented in Appendix E.

h. System Control. The Mid-Term Architecture will make use of available and planned DCS system control capabilities and resources. The preferred architecture does not require changes to the system control functions of the AUTODIN II PSNs and Network Control Center (NCC). Introduction of the I-S/A AMPE and I-S/A AMPE(E) will allow monitoring, control, reporting and restoral functions to be performed at a lower level in the network and thus, improvements should be realized in efficiency and reaction time.

As major message processing and subscriber terminating elements, the I-S/A AMPE and I-S/A AMPE(E) must perform most of the system control functions performed by the ASC and some of those performed by the PSN. The Automated Technical Control (ATEC) improvement will be completed prior to implementation of these elements, and they should be designed to take advantage of the ATEC Station level capabilities, as appropriate. Table V lists the major system control functions required in the I-S/A AMPE and I-S/A AMPE(E). Although all of the functions listed apply to both elements, the scope of the functions will be somewhat different. For example, the I-S/A AMPE(E) will collect reports from a number of I-S/A AMPEs and generate a consolidated report to the NCC or other DCS control centers.

TABLE V. I-S/A AMPE, I-S/A AMPE(E) SYSTEM CONTROL FUNCTIONS

Network Control Functions

- Patch and Test Facility
- Intersystem Interface
- Status Monitoring/Performance Assessment
  (Terminals, trunks, access lines)
- Internal Control
  - Restart/recovery
  - Program/table reload
  - Diagnostics
  - Hardware/software monitoring
- Statistics Generation
  (Circuit Outage, Circuit Performance, etc.)
- Reporting
- Circuit Restoral/Reconfiguration

Traffic Control Functions

- Message Routing
  - Primary
  - Alternate
- Message Distribution
- Traffic Flow Control
- Traffic Accountability and Integrity
- Status Monitoring/Performance Assessment
  (Traffic conditions, backlogs, resource utilization)

TABLE V. I-S/A AMPE, I-S/A AMPE(E) SYSTEM CONTROL FUNCTIONS (Continued)

- Statistics Generation
  - Billing Data
  - Traffic Volumes, Processing times, etc.
- Service Message Generation
- Reporting

Since these elements will terminate the majority of subscribers in the system it will be necessary for them to collect and report subscriber traffic statistics for billing purposes. They will also record the status information and statistics necessary to support system engineering and traffic management. The equivalent to 55-1 reports, ASC System Status reports and history information (header extracts) will be necessary. The new elements should provide the capability for further automation of the collection and reporting of this information. Additionally, the performance monitoring information provided by the PSN TAC function must be collected from the I-S/A AMPE and I-S/A AMPE(E). With the implementation of the new elements, consideration should be given to additional automation such as on-line diagnostics and downline program/table loading, to facilitate control and assistance from the NCC or other DCS operations centers.

i. Tactical Interfaces. By TRI-TAC Program definition, tactical systems will be interoperable with current and planned DCS networks. The general mode of circuit verification and system control between the DCS and tactical systems will initially be manual, with a goal of increasing automation between control elements on a cost-effective basis (via ATEC). A secure record orderwire will be required at the DCS/tactical nodal element interface, and probably at the DCS Sector to tactical Communications System Control Element (CSCE) and DCS Theater to tactical Communications System Planning Element (CSPE) as well. These orderwire cicuits should be interconnected with DCS and tactical system orderwires as necessary. In addition, processor-to-processor links should be provided between system control elements to accommodate the interchange of data base updates. The IAS elements are expected to interface through the tactical Communications Nodal Control Element (CNCE) to the tactical switches (TYC-39) as shown in Figure 17.

Selection of suitable formats and protocols for exchange of information across the DCS/Tactical interface is highly dependent upon operational procedures yet to be developed, particularly with regard to the Joint Multichannel Trunking and Switching Systems (JMTSS). Procedures also affect DCS and tactical system control software because anything short of compatible system control data bases and compatible system control processing algorithms will require translation on every interchange of system control information across the boundary. While a protocol has been recommended for use with the Tactical Communication Control Facility (Reference F), it may not provide the most effective method of passing status messages, directives, and control data across the DCS/Tactical interface. Consideration should, therefore, be given to the use of AUTODIN procedures and protocols, or development of a special protocol as the means of providing system

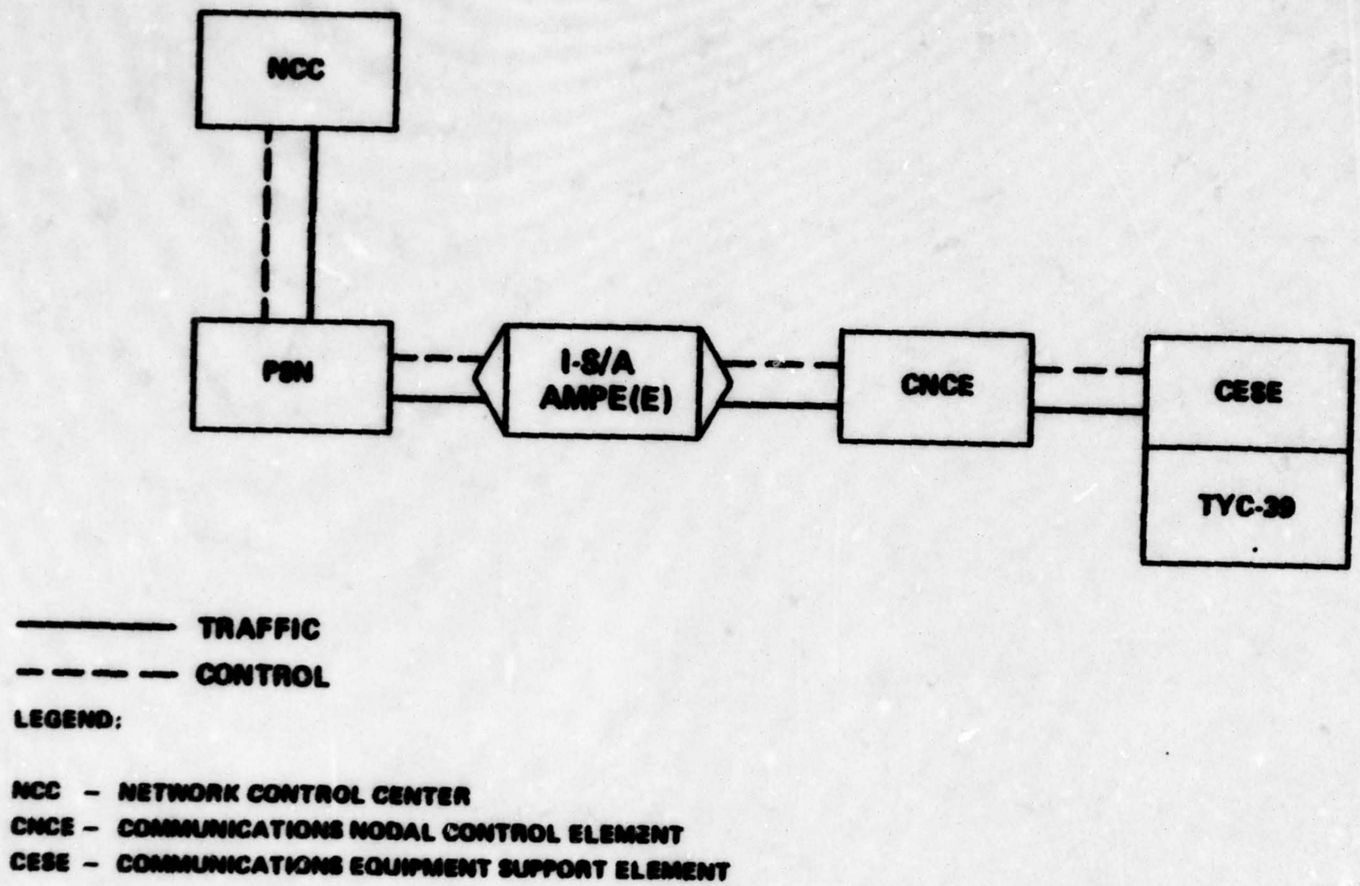


Figure 17. IAS/TRI-TAC Element Interfaces

control information flow (both near real-time and longer range) across the interface.

j. Survivability. As stated previously, enhanced survivability is a major architectural objective. Toward this end a number of decisions were made; avoid allocating critical functions to an element that is in short supply such as the CSF, and avoid bottlenecks/choke points such as home nodes or reaching the backbone only via another element. The Mid-Term IAS provides for a backbone of PSNs and packet trunks whose sole function is the efficient movement of bits in bulk. All "services" are provided in the access area close to the subscribers. The two major elements in the access area, the I-S/A AMPE and the I-S/A AMPE(E), differ from one another in the applications software and amount of hardware, such that conversion from one to the other is accomplished by adding or subtracting software/hardware in modules. Both have a Mode VI interface to the backbone and the necessary protocols so that they can readily intercommunicate via the backbone. Both terminate packet network and message network subscribers.

k. Summary. As evidenced by the preceding discussions, the perferred architecture is well defined and represents a viable approach to the Mid-Term IAS. This architecture is fully responsive to the ASD(C3I) tasking and the architectural objectives for the Mid-Term IAS established by DCA. The following paragraphs describe the two alternative architectures considered for the Mid-Term IAS in terms of their significant differences from the preferred architecture. The final paragraph in this section will compare the three alternatives and provide the principal reason for selecting the preferred architecture.

3. DESCRIPTION OF FIRST ALTERNATE ARCHITECTURE

Architecture III was ranked second in preference as a result of the evaluation of the candidate architectures. This architecture is described in the following paragraphs in terms of its differences from the preferred architecture, Architecture II. Figure 18 shows the major elements of Architecture III and their generic interconnections.

a. Elements. The major elements which comprise Architecture III are the PSN, I-S/A AMPE, I-S/A AMPE(E), CSF, and subscriber terminals. The PSN, I-S/A AMPE, and subscriber terminals are the same elements described for Architecture II. The I-S/A AMPE(E) is the same as described for Architecture II except that it does not provide the new

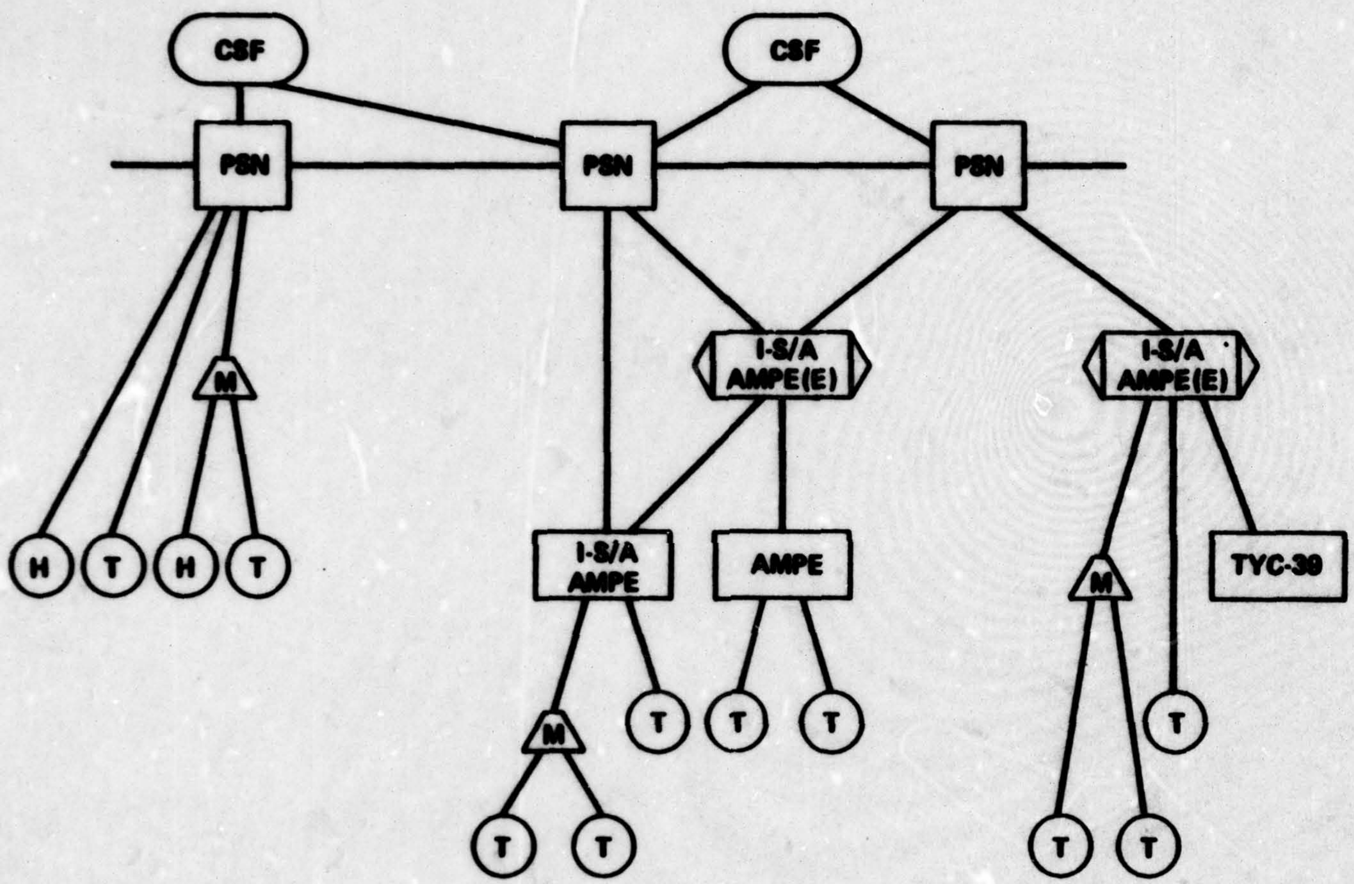


Figure 18. Architecture III Configuration

IAS network services. As in Architecture II, the I-S/A AMPE(E) performs the AMPE functions and ASC terminal support and network functions, and is a modular enhancement to the I-S/A AMPE. A Centralized Service Facility (CSF) is provided in Architecture III to perform the new functions identified for the mid-term and is also the primary expansion element to assume new functions as new requirements are identified. The CSF connects to one or more PSNs as a host computer. Although it provides user service via network access, it does not terminate subscribers.

b. Configuration/Connectivity. Connectivity options for all common elements are the same for Architecture III and Architecture II. The CSF connects only to PSNs and uses an AUTODIN II, Mode VI, Binary Segment Leader host interface. Gateways to external packet networks will be implemented in the CSF in Architecture III. New narrative/record interfaces to existing tactical elements such as the TYC-39 can be implemented in the I-S/A AMPE or I-S/A AMPE(E).

c. Protocols. As for Architecture II, Architecture III requires no new protocols to be implemented in existing elements. Link level and network level protocols are the same as for the corresponding elements of Architecture II. The CSF will communicate through the PSN network with other host computers, I-S/A AMPEs, I-S/A AMPE(E)s and terminals as a host computer, and will therefore implement SIP, TCP and THP protocols.

d. Functional Allocations. The availability of services to the various types of subscribers is the same in Architecture III as in Architecture II, except that some of the services are obtained from the CSF instead of the I-S/A AMPE(E).

The procedure for allocation of functions in Architecture III was to allocate those functions associated with new IAS services to the CSF and all ASC functions to the I-S/A AMPE(E), and then examine the functions one by one to determine whether better performance or cost savings could be realized by moving any of the functions from one element to the other. Through this approach, it was determined that the mailbox functions could be more effectively performed by the I-S/A AMPE(E), primarily because the I-S/A AMPE(E) must perform similar functions for the narrative/record message store-and-forward and retrieval services, and the mailbox service is more efficiently provided near the subscribers. These functions were therefore reallocated to the I-S/A AMPE(E) and all other functions remained as originally allocated. The CSF in Architecture III must perform those functions associated with the data teleconferencing service and E3 functions.

These functions are summarized in Table VI. Additional functions will probably be required of the CSF as a result of the implementation of gateways to other networks. The functional allocations for all other elements are the same as for Architecture II.

e. Operational Characteristics. The differences in operational characteristics of Architecture III and Architecture II are described in the following paragraphs in terms of traffic flow, security and system control.

(1) Traffic Flow. There is one major difference in the traffic flow of Architectures II and III. That difference is created by the splitting of services between the CSF and the I-S/A AMPE(E) in Architecture III. In Architecture II, all traffic entering an I-S/A AMPE requiring services not provided by the I-S/A AMPE is routed to an I-S/A AMPE(E). In Architecture III this traffic may require routing to either an I-S/A AMPE(E) or a CSF, depending on the specific service required. The I-S/A AMPE will therefore have to make the routing decisions. Likewise, traffic generated by PSN-connected subscribers may require routing to either a CSF or an I-S/A AMPE(E) for services. In this case, the subscriber will have to make the decision and address the transactions accordingly. I-S/A AMPE(E)s will also have to route some of the traffic generated by their subscribers to a CSF for additional services.

(2) Security. Security for non-E3 users is provided in Architecture III exactly as it is in Architecture II. Security for E3 users is provided in the same manner as Architecture II except that the BLACKER elements may be located at different places in the network. Trade-offs for location of these elements are discussed in Appendix E.

(3) System Control. System control considerations are essentially the same for Architecture III as for Architecture II except that an additional requirement will exist for control of the CSFs and performance of system control functions by the CSFs. The I-S/A AMPE(E) and I-S/A AMPE will be required to perform the same functions as in Architecture II. The CSF functions in this architecture consist mainly of internal status monitoring and reporting and statistics generation. The major system control functions envisioned for the CSF are listed in Table VII.

TABLE VI. CSF FUNCTIONS, ARCHITECTURE III

- Message Switching
  - Precedence Queuing/Pre-emption
  - Routing (Single Address)
  - Routing (Multiple Address - single and multiple transmissions).
- Packet Switching
  - Leader Validation
  - Precedence Queuing
  - Routing (For Conferencing)
- Protocols
  - Host-to-Node
  - Host-to-Host
  - Mode VI Link
- Message Storage and Retrieval
  - Store On-line for Retrieval
  - Message/File Access Control
  - Retrieval (By IV, Addresser, Time of Receipt, Code Word)
- System Management and Control
  - Journaling/Logging
  - Message Recovery
  - Services Message Generation
  - Flow Control
  - Statistics Generation
  - Billing
  - Status Monitoring
- Security
  - Encryption/Decryption
  - Automatic Key Variable Distribution
  - Access Control
  - User Authentication
  - Security Trace and Audit
  - Data Authentication
  - Traffic Flow Security

TABLE VII. CSF SYSTEM CONTROL FUNCTIONS, ARCHITECTURE III

Network Control Functions

- Internal Control
  - Restart/recovery
  - Program/table reload
  - Diagnostics
  - Hardware/software monitoring
- Reporting

Traffic Control Functions

- Message Routing
- Traffic Flow Control
- Traffic Accountability and Integrity
- Status Monitoring/Performance Assessment
  (Traffic condition, backlogs, resource utilization)
- Statistics Generation
  - Billing
  - Traffic Volumes, Processing Times, etc.
- Service Message Generation
- Reporting

4. DESCRIPTION OF SECOND ALTERNATE ARCHITECTURE

Architecture I was ranked third in preference as a result of evaluation of the candidate architectures. This architecture is described below in terms of its differences from the preferred architecture, Architecture II. Figure 19 shows the major elements of Architecture I and their generic interconnections.

a. Elements. The major elements of Architecture I are the PSN, I-S/A AMPE, CSF and subscriber terminals. This alternative does not include an I-S/A AMPE(E). The PSN, I-S/A AMPE and subscriber terminals used in Architecture I are the same elements as those described for Architecture II. The CSF in Architecture I provides ASC subscriber support functions for subscribers connected to PSNs and provides ASC network functions and new IAS functions for all subscribers in the network. The CSF interfaces to one or more PSNs as a host computer. It does not terminate subscribers.

b. Configuration/Connectivity. Connection options for Architecture I are essentially the same as Architecture II for the common elements. However, AUTODIN I terminals connected to PSNs will be cut-through to a CSF instead of an I-S/A AMPE(E). The CSF connects only to PSNs and uses an AUTODIN II, Mode VI, Binary Segment Leader host interface. Gateways to either packet networks or narrative/record interfaces to existing tactical elements such as the TYC-39 will be implemented in the I-S/A AMPE.

c. Protocols. Architecture I requires no new protocols to be implemented in existing elements. Link level and network level protocols are the same as for corresponding elements in Architecture II. Since the CSF interoperates through the PSN network with other elements, it will implement SIP, TCP and THP protocols. It will also perform narrative/record services and must therefore implement VMP.

d. Functional Allocation. The availability of services for the various types of subscribers is the same in Architecture I as in Architecture II, except that all services are obtained from the CSF instead of the I-S/A AMPE(E). For this architecture all ASC services as well as new IAS services were allocated to the CSF, since there is no I-S/A AMPE(E) in the architecture. E3 functions are also allocated to the CSF although they could optionally be allocated to other elements (see Appendix E). Table VIII summarizes the functions required of the CSF to provide these services. The functions performed by the other elements are the same as for Architecture II.

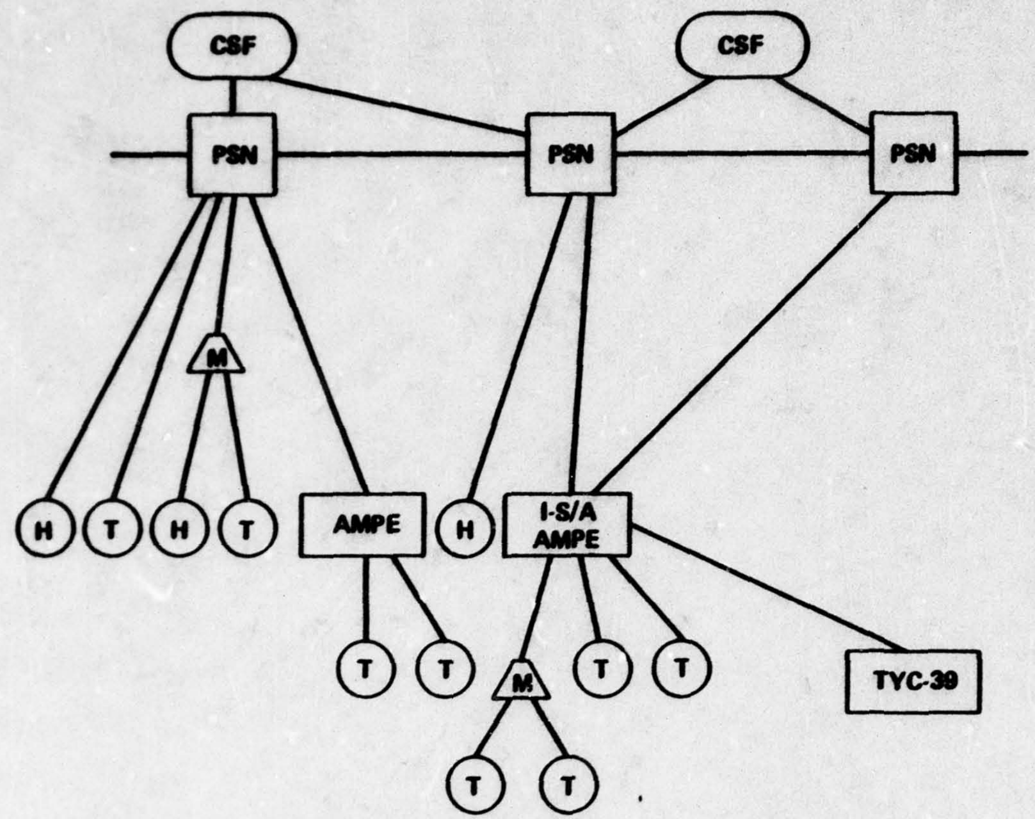


Figure 19. Architecture I Configuration

TABLE VIII. CSF FUNCTIONS, ARCHITECTURE I

MESSAGE SWITCHING
- Header Validation
- Precedence Queuing/Pre-emption
- Routing (Single Address)
- Alternate Routing (Remote)
- Multiple/Collective: Multiple Transmission/Line
Single Transmission/Line
Routing Line Segregation
- TRC/SPECAT Processing
- MCB Functions

PACKET SWITCHING
- Leader Validation
- Routing
- Precedence Queuing

FORMAT PROCESSING
- JANAP - 128
- ACP - 127
- ACP - 126
- DOI - 100
- DOI - 103
- DD - 173

CONVERSION FUNCTIONS
- Message Format: JANAP 128/ACP 127
DD 173/JANAP 128,127
Media Format (Card, Type, Etc.)
- PLA,RI/Logical Address
- PLA/RI
- Code

PROTOCOLS
- Host-to-Node
- Host-to-Host
- Link-AUTODIN I, Mode VI

MESSAGE/FILE STORAGE & RETRIEVAL
- Store Off-Line For Retrieval
- Store On-Line For Retrieval

TABLE VIII. CSF FUNCTIONS, ARCHITECTURE I (Continued)

	Intercept Storage	
	Message/File Access Control	
	Retrieve By:	Message ID
		Addressee
		Time or Receipt
		Code Word
SYSTEM MANAGEMENT & CONTROL		
	Journaling/Logging	
	Message Recovery Retrieval	
	Service Message Generation	
	Flow Control	
	Statistics Generation	
	Billing	
	Status Monitoring	
	Message Trace	
SECURITY		
	Encryption/Decryption	
	Automatic Key Variable Distribution	
	Access Control	
	User Authentication	
	S/P/TCC Validation	
	Security Trace and Audit	
	Data Authentication	
	Traffic Flow Security	

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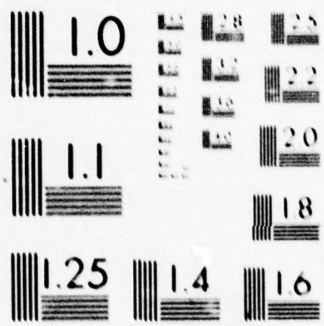

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e. Operational Characteristics. The differences in the operational characteristics of Architectures I and II, in the areas of traffic flow, security, and system control, are described in the following paragraphs.

(1) Traffic Flow. The differences in traffic flow between Architectures I and II exist because the CSF is accessed for services in Architecture I that are provided by the I-S/A AMPE(E) in Architecture II. PSN - connected subscribers will receive all their network services from the CSF. AUTODIN I - type subscribers will be cut-through the PSN to a CSF, and the CSF will provide them the ASC subscriber support and network functions as if they were directly connected. AUTODIN II type subscribers connected to a PSN will address transactions that require network service to a CSF. For I-S/A AMPE - connected subscribers, the I-S/A AMPE will determine whether transactions require a network service not provided by the I-S/A AMPE (as in Architecture II), and route the transaction to a CSF.

(2) Security. Security for non-E3 users is provided in Architecture I exactly as in Architecture II. Security for E3 users is provided in the same manner as in Architecture II except that the BLACKER elements may be located at difference places in the network. Trade-offs for location of these elements are discussed in Appendix E.

(3) System Control. System control considerations for Architecture I differ from those of Architecture II because of the existence of CSFs and the absence of I-S/A AMPE(E)s. Since the CSF services narrative/record subscribers, it will be required to perform all the system control functions of the I-S/A AMPE(E) of Architecture II except for those that deal with circuit management and control. The same functions apply to the I-S/A AMPE in Architectures I and II.

5. COMPARISON OF ALTERNATIVES AND RECOMMENDATION

The evaluation of alternative architectures presented in this section is based on the results of technical analyses performed by the support contractor to the IASA project - the Communications and Information Technology Division of Booz, Allen and Hamilton. The detailed results of all technical analyses performed are documented in Appendices B,C and D to this report. In order to facilitate evaluation of the alternative architectures, some of the most significant results of these studies are summarized in the remainder of this section.

a. Technical Factors Comparison. On the basis of the technical analyses performed as part of the evaluation process, the relative advantages and disadvantages of each alternative were identified. The following subparagraphs present the results of the evaluation process in each of the four major technical evaluation criteria.

(1) Operational Effectiveness. Alternative Architecture I with its Centralized Service Facility and direct connection of subscribers and I-S/A AMPEs to PSNs was determined to provide the best potential for performance in this evaluation category. Due to its less complex structure and direct user access, Alternative I could potentially provide a slight advantage over the other two alternatives in the areas of service delivery time and application to overseas operating environments. However, it should be remembered that each of the alternative architectures is capable of meeting the functional performance requirements and the anticipated technical performance requirements of the Mid-Term IAS. It should also be recognized that the preferred alternative (Alternative II) as well as the remaining alternative (Alternative III) provide a high degree of flexibility in the access area through dual connection of the I-S/A AMPE as well as through alternative connections for both narrative/record and computer data subscribers. The system design for the preferred architecture can take advantage of this flexibility to provide optimum service access for most users. As a result of this system design optimization, the operational effectiveness of the preferred architecture will approach the optimum available performance.

(2) Flexibility. As a result of the evaluation, it was determined that Alternative Architecture I is potentially less sensitive to changes in the day-to-day network operation within the original system design limits due to its relatively flat structure (no access area hierarchy) and its potential for load sharing of processing within a single service element (i.e., the CSF). However, Alternatives II and III were found to be significantly more flexible and less sensitive to major changes in requirements and future growth because of the greater number of connection/configuration options available within these architectures. In addition, it should be noted that the implementation of the new IAS network elements can potentially have as much impact on system flexibility as the architecture selected. For example, it is currently anticipated that the I-S/A AMPE and the I-S/A AMPE(E) will be implemented based on a multi-processor architecture. This will permit the high degree of expandability required to permit graceful evolution of the I-S/A AMPE throughout the mid-term, and protect against saturation of the I-S/A AMPE processing capability.

(3) Survivability/Availability/Maintainability. As a result of the evaluation process, it was determined that Alternative II offers a high degree of hardware/software commonality and therefore minimizes the availability/maintainability requirements of the network. In addition, Alternative II offers improved survivability through dual connection of the I-S/A AMPEs and increased independence of the I-S/A AMPEs for simple message transfer operations.

(4) Transition. Based on the evaluation process, Alternative II was found to represent the best architectural basis for transition from the near-term to the Mid-Term IAS network. In addition, Alternative II offers potentially the best architecture for continued evolution through the far-term toward the DCS objectives of both satellite broadcast backbone utilization and integration of voice and data networks. In general, Alternative II represents the least risk and difficulty for transition because only a single network service element must be implemented (i.e., I-S/A AMPE(E)). In addition, development/implementation risk is further reduced by the fact that the I-S/A AMPE(E) is derived from the currently planned I-S/A AMPE program. It should be noted that the risk assessment performed as part of the evaluation was based upon the overall IAS implementation strategy and technology trends defined by DCA (i.e., software first development approach, common family of hardware/transportable software, multiprocessor nodal architecture).

b. Cost Factors, As part of the alternative evaluation process, a comparative cost analysis was performed. This analysis identified all major cost components of the Mid-Term IAS and evaluated those factors which were found to be dependent upon network architecture. The following subparagraphs present the results of this analysis for the three major elements of cost, i.e. transmission cost, network element acquisition cost, and network element operation and maintenance cost. For more detailed discussion of cost see Appendix C.

(1) Transmission. As part of the technical analyses performed in support of the Mid-Term IASA definition, a computer model was developed and exercised to project nodal and link traffic flows as a function of architecture. This model is described in Appendix B. The results of this computer model were used to estimate the size of trunks and access lines required to support each alternative architecture. Trunk and access line distances were calculated based on currently defined PSN and AMPE locations. Transmission facility lease costs were then calculated based on available common carrier bulk tariffs for both voice grade and wide band circuits. As a result of this analysis, it was determined that the maximum projected difference in transmission costs between the "best" and the "worst" alternative architectures

was less than five percent of the total transmission cost. Further analysis confirmed that this result was not sensitive to changes in either the underlying assumptions or network configuration parameters used in the analysis. Based on this small projected difference, there is no clear preference among the alternative architectures.

(2) Network Element Acquisition Cost. The potential acquisition cost of all major network elements was estimated for each alternative architecture. As part of this process, each element was defined in terms of a standard set of hardware components (e.g., tape drives, memory, processor, display units) selected from typical state-of-the-art communications processing systems. The network elements and components were then sized based on the functional capabilities of the element, as well as the traffic (throughput) projections derived from the computer model used for transmission cost analysis. Total network element cost was then calculated based on hardware component cost estimates collected through vendor surveys and available literature.

Based on a typical network configuration for each alternative in the 1988 time frame, a projected network element inventory was developed (see Appendix C). This inventory took into account both geographic and survivability considerations in order to determine a probable minimum number of each type of element required for each alternative architecture. Based on the projected inventory and cost per element, system acquisition cost for the network elements was computed. The results of this analysis are summarized in Table IX. Cost estimates contained in this table represent the projected acquisition costs for network elements based on commercial hardware suitable to a fixed plant environment and do not include the cost of spare parts, documentation or other support costs. In addition, these costs do not include any amortization of hardware or software development costs. As evidenced by these results, the element acquisition cost does not vary greatly between the architectures. In addition, when the expected useful service life of the elements is considered, the potential difference in annual lease cost becomes less significant. Based on the small difference in cost indicated by this analysis, there is no clear preference among the alternative architectures.

(3) Operation and Maintenance Costs. Since personnel costs represent the largest single contribution to total operation and maintenance (O&M) costs, the projected personnel requirements for each alternative architecture were evaluated. As part of this analysis the manning requirements for each element type (by personnel category) were estimated based on available history of existing ASC

TABLE IX. PROJECTED NETWORK ELEMENT ACQUISITION COST

ARCHITECTURE ALTERNATIVE	NODAL ELEMENT INVENTORY	ESTIMATED COST PER ELEMENT	ESTIMATED SYSTEM ACQUISITION COST (1978 $)
I	6 CSF 78 I-S/A AMPE	CSF – $717K I-S/A AMPE – $428K	$37.7M
II	63 I-S/A AMPE 15 I-S/A AMPE(E)	I-S/A AMPE – $428K I-S/A AMPE(E) – $861K	$39.9M
III	6 CSF 66 I-S/A AMPE 12 I-S/A AMPE(E)	CSF – $434K I-S/A AMPE – $428K I-S/A AMPE(E) – $506K	$36.9M

NOTES

1. EACH ELEMENT HAS BEEN DEFINED IN TERMS OF HARDWARE COMPONENTS SELECTED FROM TYPICAL STATE-OF-THE-ART COMMUNICATIONS PROCESSING SYSTEMS.

2. COST ESTIMATES REPRESENT PROJECTED ACQUISITION COSTS FOR NETWORK ELEMENTS BASED ON COMMERCIAL HARDWARE SUITABLE TO A FIXED PLANT ENVIRONMENT, AND DO NOT INCLUDE THE COST OF SPARE PARTS, DOCUMENTATION, OR OTHER SUPPORT COSTS.

3. COST ESTIMATES DO NOT INCLUDE AMORTIZATION OF HARDWARE OR SOFTWARE DEVELOPMENT COSTS.

4. ELEMENT INVENTORIES ARE BASED ON TYPICAL 1988 NETWORK CONFIGURATIONS.

and AMPE operations. (A further discussion of manning estimates is presented in Appendix C.) Average annual costs by personnel category were computed based on available DCA cost information (Reference G). The total personnel requirements and resultant annual costs were computed for each alternative based upon the network element inventories developed as part of the acquisition cost analysis. The results of this analysis are presented in Table X. As indicated in this Table, Alternative II, The Preferred Architecture, represents a savings of approximately 200 personnel which would result in as estimated annual O&M cost reduction of approximately $4 million. This savings results primarily from the fact that Alternative II requires fewer nodal element installations than the other architectures to provide the same performance, services and geographical coverage. Although additional components of operation and maintenance cost (spares and backup equipment, facilities support, and utilities) were not calculated in this analysis, it can be expected that consideration of additional O&M factors would increase the cost advantage of Architecture II over the other alternatives.

(4) Summary Cost Comparison. A first order estimate of the total cost of the Mid-Term IAS is approximately $230 million per year (assumed 10 year economic life.) The total difference in cost between the "best" and "worst" alternatives probably represents less than 5 percent of the total cost. Considering the importance of O&M cost, Architecture II probably represents the "least cost" alternative. However, the cost difference is so small that selection of the preferred architecture solely on this basis is not recommended.

(5) Comparison of Preferred Mid-Term Architecture to Projected Baseline. In order to gain insight into the potential advantage to DCA of implementing the preferred Mid-Term IAS Architecture, the comparative cost analysis was expanded to include comparison of the preferred architecture with the 1983 baseline architecture projected to a probably 1988 configuration. The projected baseline architecture used in this analysis would incorporate only those changes and upgrades required to maintain current system capabilities. The projected baseline, when compared with the preferred Mid-Term Architecture, provides a clear indication of the impact that will result if little or no action is taken toward the evolution of the AUTODIN system. In addition, this comparison clearly emphasizes the potential cost savings of the preferred architecture.

TABLE X. PROJECTED O&M PERSONNEL COST

ARCHITECTURE ALTERNATIVE	NODAL ELEMENT INVENTORY	PERSONNEL REQUIRED	ESTIMATED ANNUAL O&M PERSONNEL COST (1977 $K PER YEAR)
I	10 PSN	630	12,220
	6 CSF	372	7,278
	78 I-S/A AMPE	+ 6,864	+ 133,068
		7,866	152,566
II	10 PSN	630	12,220
	15 I-S/A AMPE (E)	1,470	28,425
	63 I-S/A AMPE	+ 5,544	+ 107,478
		7,644	148,123
III	10 PSN	630	12,220
	6 CSF	276	5,460
	12 I-S/A AMPE (E)	1,128	21,840
	66 I-S/A AMPE	+ 5,808	+ 112,596
		7,842	152,116

NOTES:

1. NODAL ELEMENT INVENTORIES ARE BASED ON TYPICAL 1988 NETWORK CONFIGURATIONS.

2. PERSONNEL REQUIREMENTS REPRESENT SITE TOTALS, ASSUMING FOUR SHIFTS.

3. AVERAGE YEARLY COSTS ARE BASED ON PERSONNEL RATES FOUND IN REFERENCE 6.

The projected 1983 baseline architecture is based on the following assumptions:

- o ASCs retained in operation with minimum essential hardware/software subsystem replacement

- o AMPEs retained in all current locations and replaced at the end of their useful service life with a "standardized" AMPE.

Base on current DoD policy, the projected baseline architecture includes provision for replacement of existing AMPEs with some form of standardized AMPE. However, because these equipments would not have the additional capability of the I-S/A AMPE used in the preferred architecture, it is unrealistic to assume that consolidation could be achieved in the projected 1983 baseline architecture. Therefore, the number of AMPEs projected for the 1988 configuration was derived from current and planned AMPE requirements (see Appendix A).

A comparison of projected network element acquisition cost for the preferred architecture versus the projected baseline is presented in Table XI. As indicated by this table, total estimated acquisition cost of the preferred architecture is approximately $3.3 million greater than the projected baseline.

The comparison of operation and maintenance personnel costs for the preferred architecture versus the projected baseline is presented in Table XII. As evidenced by this table, the preferred architecture offers a potential net savings of over 2500 personnel with a resultant net cost savings of almost $50 million per year. It should be noted that the cost analysis takes into account the fact that many of the existing and planned AMPE sites eliminated through consolidation will revert to local Terminal/message center operation. As a result, many of the O&M personnel formerly required at the AMPE sites will be retained for operation of the terminal/message centers . The magnitude of the potential savings indicated by this analysis demonstrates clear opportunity for significant reduction of total AUTODIN system operation and maintenance cost through implementation of the preferred Mid-Term IAS Architecture.

c. Recommendation. Based on the results of the evaluation process, the preferred architecture described in paragraph 2 of this section is recommended as the Mid-Term Architecture for the Integrated AUTODIN System. This architecture is fully responsive to

TABLE XI. NODAL ELEMENT ACQUISITION COST COMPARISON

	REQUIRED ACQUISITIONS	ESTIMATED COST PER ELEMENT	(1978 \$) SYSTEM COST
MID-TERM ARCHITECTURE (II) (1988)	15 I-S/A AMPE (E) 63 I-S/A AMPE	\$861K \$428K	\$39.9M
PROJECTED BASELINE (1988)	107 AMPE (REPLACEMENT)	\$342K	\$36.6M

NOTES:

1. EACH ELEMENT HAS BEEN DEFINED IN TERMS OF HARDWARE COMPONENTS SELECTED FROM TYPICAL STATE-OF-THE-ART COMMUNICATIONS PROCESSING SYSTEMS.

2. COST ESTIMATES REPRESENT PROJECTED ACQUISITION COSTS FOR NETWORK ELEMENTS BASED ON COMMERCIAL HARDWARE SUITABLE TO A FIXED PLANT ENVIRONMENT, AND DO NOT INCLUDE THE COST OF SPARE PARTS, DOCUMENTATION, OR OTHER SUPPORT COSTS.

3. COST ESTIMATES DO NOT INCLUDE AMORTIZATION OF HARDWARE OR SOFTWARE DEVELOPMENT COSTS.

4. ELEMENT INVENTORIES ARE BASED ON TYPICAL 1988 NETWORK CONFIGURATIONS.

5. SUNK COSTS, INCLUDING PSNs, TERMINALS, ETC., HAVE BEEN EXCLUDED FROM THE COST COMPARISON.

6. THE AMPEs SHOWN IN THE PROJECTED BASELINE ELEMENT INVENTORY ARE STANDARDIZED AMPEs WHICH REPLACE CURRENT (NEAR-TERM) AMPEs DURING THE MID-TERM.

7. THE COST OF REPLACEMENT AMPEs WAS ESTIMATED AT 80% OF THE I-S/A AMPE COST.

TABLE XII. O&M PERSONNEL COST COMPARISON

1983 BASELINE EXTRAPOLATED TO 1988	TOTAL PERSONNEL	TOTAL COST ($K/YR)	MID-TERM ARCHITECTURE (III)	TOTAL PERSONNEL	TOTAL COST ($K/YR)
• CONUS:			• CONUS:		
8 PSN	504	9,776	8 PSN	504	9,776
4 ASC	462	8,776	8 I-S/A AMPE (E)	704	15,100
104 AMPE	9,224	178,518	50 I-S/A AMPE	4,400	85,300
	+	+	22 AMPE (CURRENT)	2,168	40,328
	10,180	197,070		+ 7,776	+ 150,504
• OVERSEAS:			• OVERSEAS:		
2 PSN	126	2,444	2 PSN	126	2,444
7 ASC	791	15,268	7 I-S/A AMPE(E)	686	13,265
25 AMPE	3,125	60,465	13 I-S/A AMPE	1,144	22,178
	+	+	10 AMPE (CURRENT)	960	18,340
	4,042	78,267		+ 2,916	+ 56,227
• SAVINGS DUE TO COLOCATION OF PSN's WITH ASC's (4 IN CONUS, 2 OVERSEAS)	− 120	− 2,388	• MANNING REQUIREMENTS FOR 29 AMPES WHICH REVERT TO LOCAL TERMINAL/MESSAGE CENTER STATUS AS A RESULT OF CONSOLIDATION.	+ 870	+ 16,560
• TOTALS:	14,102	272,940	• TOTALS:	11,564	223,370
NET SAVINGS ACHIEVED BY MID-TERM ARCHITECTURE:				2,538	$ 49,570 · 10^3/YR

NOTES:

1. PERSONNEL LEVELS AND RATES ARE THOSE LISTED IN TABLE VI APPENDIX C.
2. COST CALCULATIONS ARE BASED ON TYPICAL 1988 NETWORK CONFIGURATIONS.
3. THE PROJECTED BASELINE INCLUDES CURRENT AMPES WHICH WILL BE IN SERVICE THROUGH 1988 AS WELL AS STANDARDIZED AMPES WHICH REPLACE CURRENT AMPES DURING THE MID-TERM.

ASD (C3I) guidance and is capable of meeting the architectural objectives for the Mid-Term IAS described in Section I of this report. The preferred architecture is consistent with the constraints on the Mid-Term IAS defined in Section II (paragraph 2), and is capable of providing all of the required services and functions defined for the Mid-Term IAS (Section II, paragraph 4). In summary, the preferred architecture offers significant potential benefits to both DCA and the entire DoD AUTODIN user community:

- Reduced Cost of Ownership - The preferred architecture offers significant opportunity for reduction in O&M cost through standardization of service/agency message processing and communications hardware, software and operating procedures. Additional savings will result from consolidation of network service elements and local user message processing elements in the access area. Finally, a major cost savings will be possible through personnel reduction as a result of consolidation of access area AMPE sites into joint service/agency multi-user I-S/A AMPE configurations.

- Enhanced Survivability. The preferred architecture will allow improved access reliability for users through multiple interconnection of network access nodes (I-S/A AMPE and I-S/A AMPE(E)). In addition, since user access nodes are not dependent on higher level elements for most normal message traffic, the loss of a single network element will have little effect on total system operation. In fact, the preferred architecture provides for an almost continuous graceful degradation of service in the face of network node/link losses.

- Improved Performance. The preferred architecture will permit the introduction of significant new telecommunication services and features. In addition, the improved access arrangements and distribution of service nodes throughout the access area will permit improved speed of service and overall network responsiveness to most areas. Furthermore, the flexibility inherent in the preferred architecture will allow the future AUTODIN system to accommodate many unique user requirements without penalty to other users.

- Evolutionary Transition. The preferred architecture can be implemented in a smooth evolutionary process from the 1983 Near-Term Architecture. In addition, the preferred architecture provides a framework for continued evolutionary development of the IAS through 1988 and beyond.

Among the potential benefits of the preferred architecture, the most important may well be its ability to evolve in a smooth and orderly process from the current AUTODIN network. In order to demonstrate the feasibility of this process, the final Section of this report, which follows, presents a preliminary transition plan for the implementation of the preferred architecture.

SECTION IV

TRANSITION

1. INTRODUCTION

a. Background. In accordance with ASD(C3I) direction, the IAS will evolve in a deliberate and continuous fashion from today's communication system and services to the more sophisticated communication methods of the future. This realistic guidance precludes the possibility of any single "turnkey" type of operation where the system is replaced by another at some pre-established date. Hence, the need for a smooth transition over the next decade becomes paramount to the IAS architectural strategy. Continuity of service and user transparency emerge as important transitional considerations. The incremental addition of new network elements (e.g., PSNs and I-S/A AMPEs) and the concomitant phasing out of obsolete equipment (e.g., ASCs and AMPEs) will characterize the evolution.

The first cut at defining a transition plan took the approach that the transition must be performed within the framework of a circa 1990 IAS, i.e., the employment of equipment, techniques, and philosophies must be consistent with the full range of potential circa 1990 architectures. These considerations and others were factored by DCA into a general approach to achieving evolutionary transition and were presented in References A and H. Under that general approach, transition strategies were postulated for two markedly different, but feasible, circa 1990 architectures: one based on terrestrial switching, the other based on broadcast satellite use. It was assumed that the architecture selected for circa 1990 would lie somewhere between these extremes. Since each of the alternatives considered, although differing widely in the backbone architecture, proceeds initially from the present (1978) architecture in the same manner, it was concluded that any chosen architecture would require the same sequence of events in the near-term. Consequently, a single near-term transition approach was developed. In order to ensure the continued evolution of the IAS beyond the near-term, a transition approach for the mid-term must be defined.

b. Purpose. The objective of this section of the report is to demonstrate the feasibility of achieving the Mid-Term IAS in an evolutionary manner by defining a preliminary transition approach for the Mid-Term.

Paragraph 2 serves as a point of departure to the Mid-Term IAS transition approach by reviewing and updating near-term activities and milestones. Paragraphs 3 through 8 postulate a transition strategy, with alternative approaches where applicable, for evolving from the near-term to the mid-term. Finally, the sequence of events, milestones, and interdependence of activities for the preliminary transition approach are presented in Paragraph 9.

2. NEAR-TERM IAS

The Near-Term IAS, expected to be fully implemented by late 1983, is depicted in Figure 20. The following paragraphs describe the network components, functional allocation, and transitional approach for achieving the Near-Term IAS.

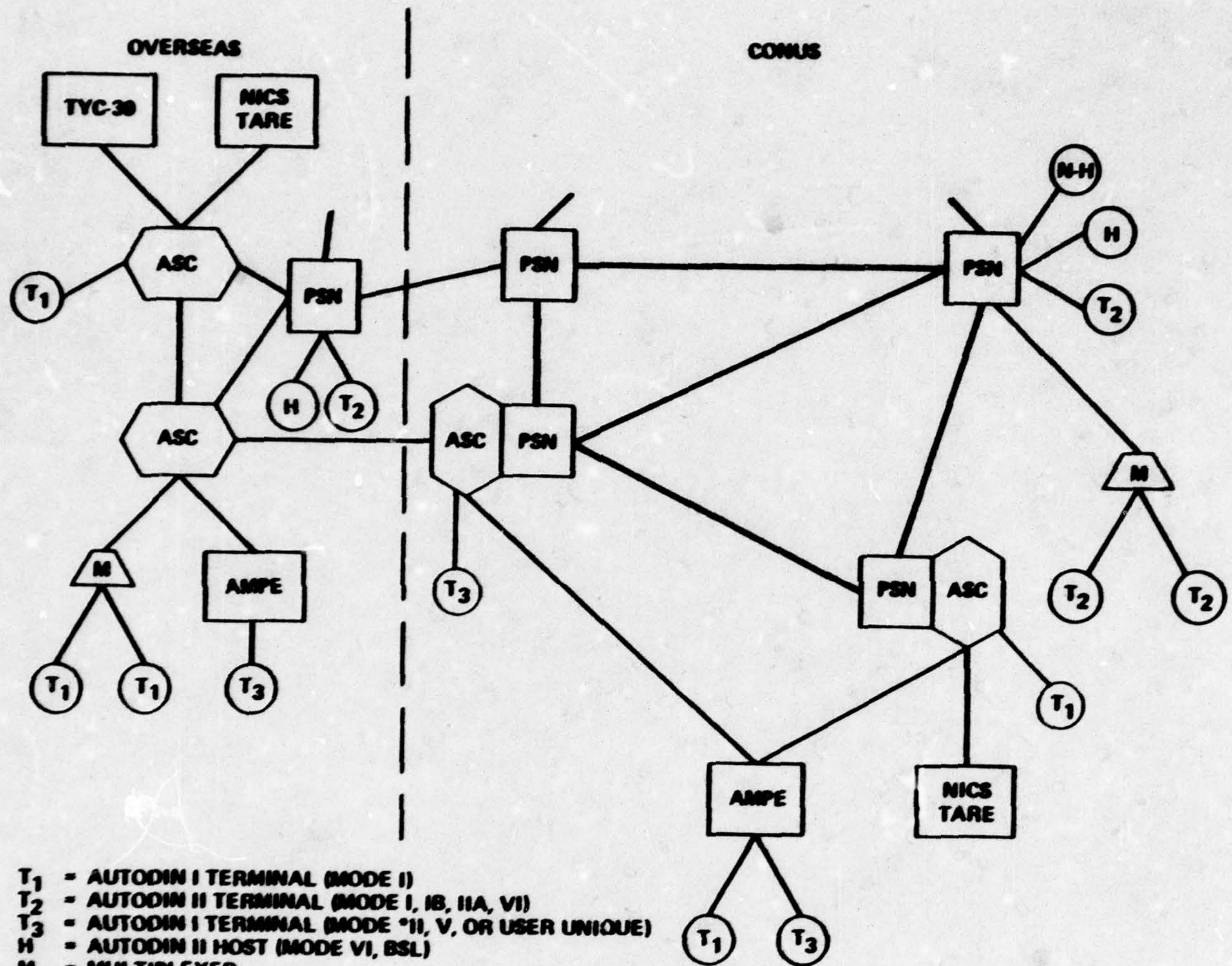
a. Network Components. In the near-term, the IAS will consist of a set of elements that satisfy validated service requirements with no technological risk.

(1) AUTODIN Switching Center (ASC). By 1983, eleven to thirteen ASCs will be in operation (six government-owned overseas, one leased in Hawaii, and four to six leased in CONUS). Overseas ASCs will either be trunked to CONUS ASCs or receive trunking via PSNs. CONUS ASCs will receive their trunking through the PSNs when they are colocated to a PSN (note: CONUS PSNs will be colocated and directly connected to ASCs). Those ASCs at which a PSN will not be initially installed will use dedicated circuits for trunks.

Functionally, the ASC will be essentially unchanged from what exists today. It will continue to provide all store-and-forward functions such as message retrieval, intercept storage, multiple address processing, code conversion, and format conversion.

(2) Packet Switch Node (PSN). Between four and six interconnected CONUS PSNs will be in place and operational by 1983. Four of these will be colocated with the remaining CONUS ASCs and will have a Mode VI serial communications interface capable of multiple virtual connections to the ASC. The PSNs will be interconnected by multiple packet trunks operating at speeds of 50 kbps or greater derived from common carrier facilities. These trunks will be link encrypted.

In addition to providing packet switching service to all AUTODIN II subscribers, the PSN will terminate AUTODIN I, Mode I subscribers e.g., AMPE. All traffic so received will be "cut-through" to a home ASC for normal AUTODIN I processing.



T_1 = AUTODIN I TERMINAL (MODE I)
T_2 = AUTODIN II TERMINAL (MODE I, IB, IIA, VI)
T_3 = AUTODIN I TERMINAL (MODE *II, V, OR USER UNIQUE)
H = AUTODIN II HOST (MODE VI, BSL)
M = MULTIPLEXER
N-H = NETWORK FRONT-END (NFE) CONNECTED HOST

* NOT ALL MODES AVAILABLE AT ALL NODES

Figure 20. Near-Term IAS Architecture

(3) Automated Message Processing Exchange (AMPE). Defense Agency and MILDEP projections indicate that the number of AMPEs that will be operational in the Near-Term IAS will be approximately 114. Installations are being evaluated on a case-by-case basis. AMPEs will be terminated on either PSNs or ASCs using AUTODIN I, Mode I protocol. For availability and backup purposes, some AMPEs will probably be dual connected, i.e., connected to either two PSNs, two ASCs, or a PSN and an ASC. In each case the connections will be extended to two different ASCs to receive service.

The following AMPE types will be in place and operational in the Near-Term IAS:

- o AMME - Automated Multi-Media Exchange (Army)
- o LDMX - Local Digital Message Exchange (Navy)
- o NAVCOMPARS - Naval Communications Processing and Routing System (Navy)
- o AF AMPE - Air Force Automated Message Processing Exchange
- o ICATS - Intermediate Capacity Automated Telecommunications System (Air Force)
- o STREAMLINER - Project title of a family of Automated Communications Facilities (NSA)
- o DLA - Defense Logistics Agency.
- o Near-Term Inter-Service/Agency AMPE

All of the AMPEs to varying degrees provide and will continue to provide through the near-term:

- o AUTODIN Terminal System Functions. This category accounts for all functions required of an AUTODIN subscriber terminal.
- o Telecommunications Center Functions. This category includes those functions performed by a telecommunications center.
- o Customer Assistance Functions. This category includes those functions that can be performed more efficiently at a telecommunications center than at a user facility.

A specific breakdown of these categories is provided in Reference A.

The precise functional composition of the AMPEs varies by Service/Agency as each AMPE was designed and developed independently to provide mission-oriented functions and features. Consequently, it is difficult for each AMPE to be utilized by subscribers outside the intended community of interest. AMPE Phase I and Phase II Functional Comparison studies have addressed this problem and concluded that there is a large amount of functional similarity among the AMME, LDMX, NAVCOMPARS, and AF AMPE systems. A third phase of that AMPE comparison analysis is currently underway to determine the feasibility of establishing functional standards and upgrading existing AMPEs to allow interservice use of AMPEs in the near-term. Additionally the feasibility of using the AF AMPE as a baseline for a Near-Term Inter-Service/Agency AMPE is under study.

(4) Subscriber Terminals. The Near-Term IAS will accommodate a wide variety of subscriber terminals, ranging from Model-28 teletypewriters to sophisticated software programmable devices such as Standard Remote Terminals (SRTs) and ADP hosts.

Depending on the service needs of the subscriber, subscriber terminals will be terminated on AMPEs, ASCs, or PSNs. The various termination alternatives available to a subscriber are shown in Table XIII. While it would appear that the various programmable devices could be reprogrammed to interface directly with a PSN, each device should be considered on an individual basis to determine the desirability, feasibility and cost-effectiveness of doing so.

(5) Multiplexers. Multiplexers will be employed where deemed appropriate to save communications cost. Multiplexers will be connected to a single access device (i.e., AMPE, ASC or PSN).

b. Near-Term Transition Strategy. The strategy adopted for transitioning to the Near-Term IAS is characterized by a sequence of events, target dates, and the interdependencies of events. Table XIV lists the required activities and their associated target dates in chronological order. Figure 21 presents the transition activities as a milestone chart to aid in visualizing their interdependencies.

3. MID-TERM IAS

In keeping with the ASD (C3I) guidance, the Mid-Term IAS will evolve gracefully from the Near-Term IAS to the selected alternative of the Mid-Term IAS. Figure 22 depicts the Mid-Term IAS as it will

TABLE XIII. NEAR-TERM TERMINATION POLICY

NETWORK ELEMENT		TERMINATING DEVICE AMPE	ASC	PSN
TERMINAL	AMPE	NO	YES	YES*
	AUTODIN I MODE I TERMINAL	YES	YES	YES*
	AUTODIN I MODES II & V TERMINAL	YES	YES	NO
	AUTODIN II TERMINAL	NO	NO	YES
	HOST (AUTODIN II)	NO	NO	YES

* TERMINATED ON A PSN BUT HOMED TO AN ASC.

TABLE XIV. NEAR-TERM IAS TRANSITION PLAN

Activity	CY Target Date
a. Field AMPEs	In Progress
b. Overseas (O/S) ASC Memory Upgrade	1978
c. CONUS ASC Tape Replacement by Disc	1978
d. Start Fielding SRTs	1978
e. Close One PAC Area ASC (Buckner)	1978
f. Close Second PAC Area ASC (Clark)	1979
g. Select LMD for Near-Term I-S/A AMPE	1979
h. IOC AUTODIN II Phase I (3 PSNs)	1979
i. O/S ASC Tape, Card Reader and Printer Replacement; Upgrade of Patch-and-Test Facilities	1980
j. Complete Fielding AUTODIN II Phase I (4 PSNs)	1980
k. Start Phase Out CONUS ASCs; Rehome Affected Subscribers	1980
l. Field Initial O/S AUTODIN II PSNs	1981
m. Start AUTODIN II CONUS Expansion	1981
n. Complete Fielding AMPEs	1982
o. Start Fielding Near-Term I-S/A AMPE	1982
p. Complete AUTODIN II CONUS Expansion	1983
q. Complete Phase Out (up to Four) CONUS ASCs	1983
r. Near-Term IAS Architecture Achieved	1983

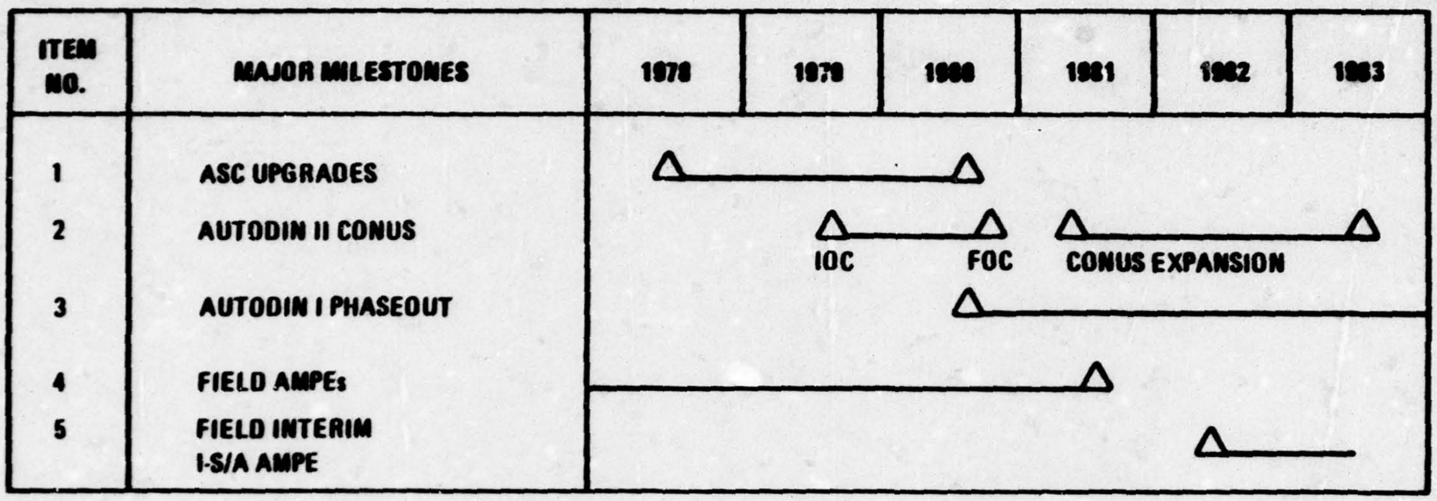


Figure 21. Near-Term IAS Milestones

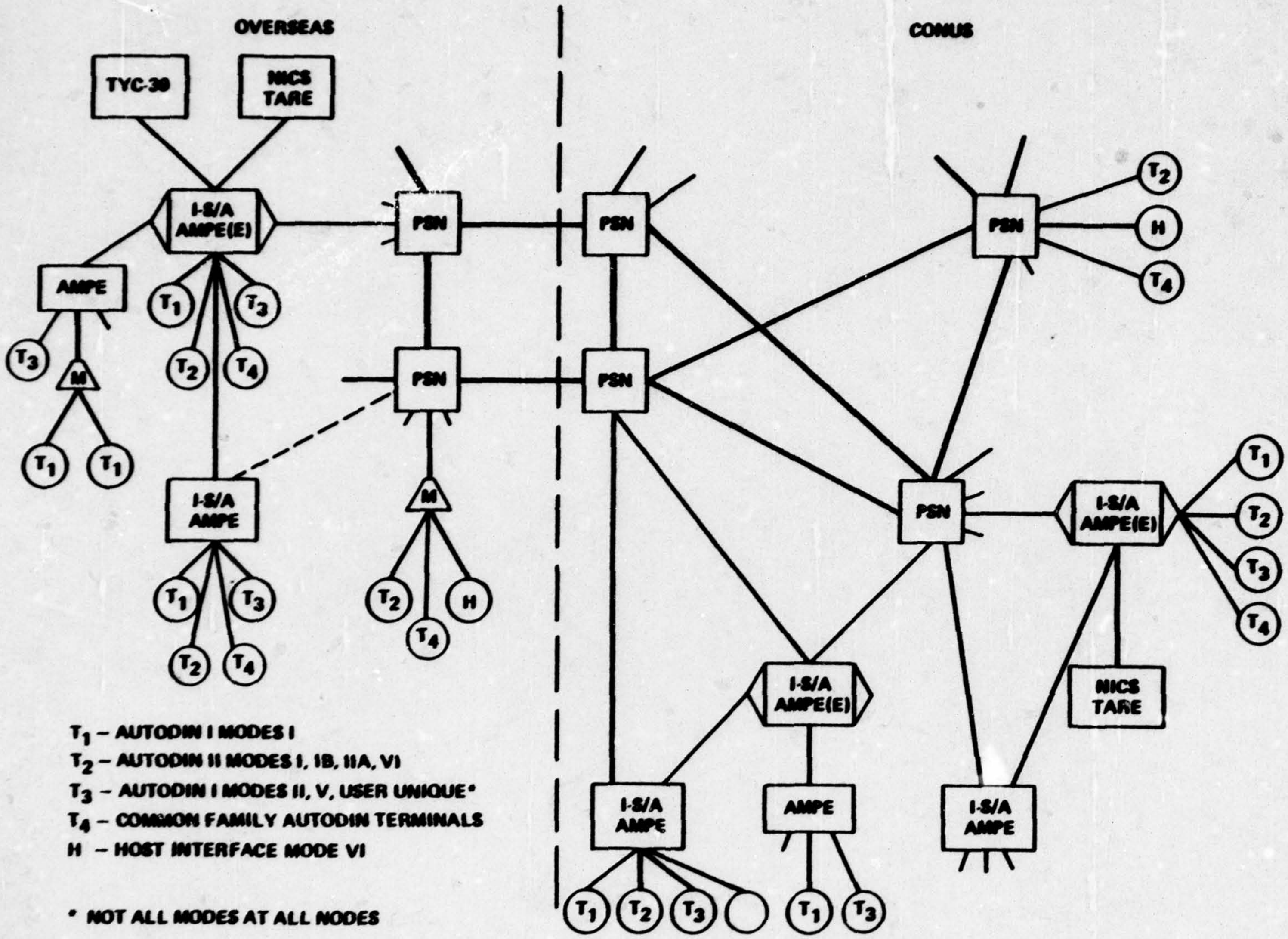


Figure 22. Mid-Term IAS Architecture

appear circa 1988 if the preferred architecture is implemented. The following paragraphs detail the components, functional allocation, and strategy for achieving an evolutionary transition.

a. General Mid-Term Objectives. In contrast with the Near-Term IAS which is constrained by the use of existing technology and equipment, the Mid-Term IAS begins to exploit the advantages of state-of-the-art communications hardware and software techniques. Accordingly the mid-term transitional strategy is driven by the following architectural objectives:

- o Replace equipment as it becomes outdated with new or augmented standardized network elements (e.g., replace AMPEs with I-S/A AMPEs)
- o Preserve continuity of existing network services
- o Provide for needed new services
- o Develop and field new functional capabilities (e.g., end-to-end encryption with key distribution centers)
- o Reduce O&M costs
- o Expand AUTODIN II to provide a worldwide data backbone
- o Enhance system survivability
- o Enhance tactical and allied forces interoperability.

b. Transition Issues. With respect to these objectives, there are a number of transition issues that require amplification and resolution. These include:

- o User Transparency
- o Functional Allocation/Reallocation
  - Transfer of functional responsibility (e.g., ASC to I-S/A AMPE(E))
  - Field testing of new functional capabilities for user acceptance
- o Replacement/Integration Strategy
  - Incremental addition of new network elements
  - "Cutover" strategies

- Phasing out of obsolete or non-cost effective equipment

- Rehoming affected subscribers

- Impact on remaining network elements

o Overseas (O/S) implications

These issues and objectives have been factored into an overall IAS transition strategy which can in turn be subdivided into more detailed lower level (network element) transition strategies. The intent of the subsequent discussions is to illustrate the overall Mid-Term transition strategy by identifying transition alternatives at each level.

c. Network Elements. In addition to the near-term network elements, which will exist into and in some instances through the mid-term, a number of new network elements must be implemented in the mid-term.

(1) Inter-Service/Agency AMPEs (I-S/A AMPE and I-S/A AMPE(E)). The I-S/A AMPE and I-S/A AMPE(E) will be used to satisfy all requirements for new or replacement AMPEs as well as providing the services and functions needed in the IAS. An enhanced version of this network element, the I-S/A AMPE(E), in addition to providing AMPE functions and services, will assume the functional role of the ASC and will provide network services currently outside the scope of the Near-Term IAS.

(2) Centralized Service Facility (Contingency Option). Although the preferred Mid-Term IAS architecture does not include this element, the CSF represents a potential system level transition option. This option will be exercised only in the event that new requirements emerge that cannot be accommodated within the I-S/A AMPE(E) program.

(3) Common Family of Terminals (CFT). A new generation of subscriber equipment will be introduced in the Mid-Term IAS time frame.

(4) Security Components. An end-to-end encryption (E3) capability derived from the BLACKER hardware and software developments will be introduced by the Mid-Term IAS.

d. Transition Objectives. Relative to the Mid-Term IAS network components, transition planning focuses on meeting the following specific transition objectives:

- o Implementation of the I-S/A AMPE Family of Equipments
- o Expansion of the PSN backbone
- o Introduction of the CFT
- o Integration of E3 security into the operational network.

The transition issues relative to each of these objectives are discussed in detail in the remainder of this section.

4. IMPLEMENTATION OF I-S/A AMPE FAMILY

a. I-S/A AMPE Family Development Approach. The I-S/A program is based on the development of a common standardized set of hardware and software modules. The modular approach of this program coupled with the use of a high order compiler language (HOL) for software development should alleviate critical manpower and unique software support requirements that characterized the independent AMPE programs. Accordingly, this approach should result in reduced maintenance costs and greater flexibility in sizing and configuring the access area. Also inherent to this approach is the potential for providing specific functional modules locally where required or desired.

b. I-S/A AMPE Roles. The I-S/A AMPE family of equipment will fill three distinct roles in the Mid-Term IAS:

- o Replacement of AMPEs
- o Replacement of ASC
- o Provision of new IAS service

The I-S/A AMPE family implementation approach reflects these three distinct roles. Accordingly, the following subsections present the transition issues relevant to the I-S/A AMPE in each of its projected roles.

c. AMPE Replacement. Each I-S/A AMPE implementation, enhanced or otherwise, will provide certain basic capabilities that are currently allocated to the AMPE, e.g., journalling, retrieval, intercept, PLA/RI conversion, format and code conversion, and terminal interface. In other words, every I-S/A AMPE and the enhanced version will function as an AMPE replacement as a minimum. The precise configuration of an I-S/A AMPE will vary by location but will be based on the common family of hardware/software modules. Unique functions will be accommodated on an "as required" basis.

As noted previously, the lack of AMPE standardization makes it difficult for a subscriber outside the intended community of interest to use an AMPE. The I-S/A AMPE, however, will provide service to all Service/Agency users. Furthermore, R/Y consolidation will also be achieved in this network element. Consequently, as the IAS evolves, it is anticipated that the replacement of AMPEs with I-S/A AMPEs will lead to consolidation of AMPE sites and an accompanying reduction in maintenance cost. (Reference Appendix A).

The target date for the AMPE replacement modules of the I-S/A AMPE is scheduled for the latter part of 1983. Subsequent to that milestone all AMPE implementations, new or replacement, will be I-S/A AMPEs. Furthermore, any AMPEs scheduled to be replaced in the 6 month period immediately preceding introduction of the I-S/A AMPE should be delayed so that they can be replaced by an I-S/A AMPE. Ultimately all current AMPEs will be phased out in favor of the I-S/A AMPE.

The actual AMPE replacement strategy and total I-S/A AMPE requirements will be defined by DCA in coordination with potential Service/Agency users. Nevertheless, certain characteristics of the transition can be rather safely stated. These relate to the transition issues of:

- Cutover
- General Replacement Strategy
- Survivability/Availability
- Overseas Implications
- Support Requirements

These transition issues are discussed in the following subparagraphs.

(1) Cutover to I-S/A AMPE. Since continuity of service and user transparency are primary transition objectives, the replacement of an AMPE will require a smooth cutover. Three alternatives have been considered toward this end:

- o Alternative 1: Physically install an I-S/A AMPE and establish circuits to two higher level elements. Dual capture "back side" AMPE Circuits on both AMPE and I-S/A AMPE. Operationally test I-S/A AMPE. Cutover from AMPE to I-S/A AMPE and close down AMPE.

- o Alternative 2: Physically install and home I-S/A AMPE as above. Tie AMPE onto back side of I-S/A AMPE in addition to its normal homing. Individually cutover back side AMPE circuits. Close down AMPE.

- o Alternative 3: Rehome back side AMPE users to nearby nodes (i.e., PSNs, I-S/A AMPE(E), I-S/A AMPE, or AMPEs). Close down and physically remove AMPE. Install I-S/A AMPE and home to two higher level elements. Re-establish back side users on the I-S/A AMPE.

Alternative 3 significantly impacts other network elements and should be considered only when physical limitations demand AMPE removal prior to I-S/A AMPE installation. Alternative 1 is preferred over Alternative 2 because it allows I-S/A AMPE test and evaluation in a near-operational environment prior to final cutover. Determination of a preferred alternative will be influenced by local factors such as circuit cost and availability.

(2) AMPE Replacement Strategy. The transition from AMPEs to I-S/A AMPEs will be marked by the incremental addition of I-S/A AMPEs to the network over the next dozen years primarily based on the remaining useful service life of existing AMPEs. Consequently, the replacement of some AMPEs can be absorbed by I-S/A AMPEs that were fielded for other reasons (i.e., to replace a nearby AMPE or to satisfy new requirements for I-S/A AMPE service). This will happen when an AMPE located close to an operational I-S/A AMPE requires replacement. In this event, AMPE subscribers could be rehomed to the nearby I-S/A AMPE (note: it may not be the same I-S/A AMPE for all users; in particular, remote users) as an interim measure, followed by cutover and removal of the AMPE. Alternatively, the AMPE itself can be rehomed to the nearby I-S/A AMPE and each subscriber cutover independently (as in Alternative 2 above). Both of these options are consistent with transition objectives and each allows for minimizing transmission costs by addressing each subscriber individually.

(3) Survivability/Availability. To enhance survivability and availability, I-S/A AMPEs will probably be dual homed to two higher level elements. Specifically, the I-S/A AMPE can be terminated on two PSNs, two I-S/A AMPE(E)s, or one PSN and one I-S/A AMPE(E). As discussed in Section III it is preferable to connect the I-S/A AMPE to a PSN and an I-S/A AMPE(E) in order to facilitate both optimum traffic routing and enhanced survivability. The AUTODIN Management Index (AMIE), the Worldwide AUTODIN Restoral Plan and other management plans and data bases will be modified at an early date to incorporate the I-S/A AMPEs and to take advantage of the survivability and availability features the I-S/A AMPE will bring to the IAS. In addition to the ability of the network to provide more locations for service to all users, the cost factors of providing capabilities such as dual homing will be favorably affected.

(4) Overseas AMPE Implications. AMPE equipments located overseas may reach the end of their useful service life and require replacement prior to full introduction of PSN or I-S/A AMPE(E) service overseas. In this event, homing of replacement I-S/A AMPEs presents two options. The I-S/A AMPEs can be homed to CONUS PSNs or I-S/A AMPE(E)s; however, the use of intercontinental trunks for this purpose is undesirable from both cost and survivability considerations. Alternatively, I-S/A AMPEs could be homed to a remaining overseas ASC via the available AUTODIN I, Mode I interface. This would provide an interim solution until eventual ASC replacement.

(5) AMPE Support Requirements. Based on AMPE service life projections and installation schedules, a significant number of AMPEs will not require replacement in the Mid-Term time frame and, therefore, must be supported into the far-term.

d. ASC Replacement. The enhanced I-S/A AMPE is a modular expansion of the AMPE replacement I-S/A AMPE that contains (in addition to its AMPE replacement functions) all of the functions of the ASC, e.g., message switching, multiple address routing. Because of the high cost associated with the operation and maintenance of ASCs, a high priority will be placed on phasing out the ASCs. The initial installations of I-S/A AMPE(E)s, projected for early 1984, will be carefully planned so that each installation is accompanied by the closure of an ASC.

Because it is undesirable to make a transition decision that will be reversed by a later transition consideration, ASC closings cannot be addressed independently. Care must be taken with each transition step so that a smoother transition to the final Mid-Term configuration can be achieved.

In the near-term the number of ASCs in CONUS and Overseas will be reduced. With the implementation of I-S/A AMPEs and additional PSNs, the ASCs will be required only to perform the message processing function for store-and-forward traffic. It is these functions which the I-S/A AMPE(E) will be designed to perform. Hence elimination of ASCs becomes possible.

(1) Overseas ASC Trunking. The primary issue in overseas trunking is maintaining diversity in the event of failures. The preferred connection for trunking is via the PSNs but additional trunk connections e.g., O/S I-S/A AMPE(E) to CONUS PSN may be desirable until sufficient PSNs are fielded overseas. Prior to fielding the I-S/A AMPE(E), the ASCs will in some cases maintain their own trunking sub net. When the I-S/A AMPE(E) is fielded, connection between ASCs would be maintained only if PSN connections are found to be inssuficient.

(2) Rehoming Directly Connected ASC Subscribers. AUTODIN I subscriber terminals that are directly connected to an ASC must be rehomed. Rehoming of terminals will be evaluated on a case-by-case basis. AUTODIN I terminals can be rehomed alternatively to an I-S/A AMPE, I-S/A AMPE(E), or, if a Mode I terminal, to an I-S/A AMPE(E) via PSN cut-through. Consideration for each affected terminal should be given to minimizing transmission cost and to the final Mid-Term IAS configuration. A less attractive rehoming option is to rehome to an AMPE. This would result in another rehoming, however, when that AMPE is phased out. This is inconsistent with planning for a smooth transition.

(3) ASC-PSN Connections. CONUS ASCs are connected to the PSN for two purposes:

- to receive CONUS trunking
- to service message switching requests from remote CONUS subscribers

Once the overseas trunking and direct subscriber connection problems are resolved, the ASC-to-PSN connection will only be used for message switching service requests. The PSNs must then route these requests to an I-S/A AMPE(E). This will permit ASC deactivation.

(4) Cutover. The actual installation of an I-S/A AMPE(E) is identical in cutover procedures to the installation of an I-S/A AMPE with one exception. That occurs when the I-S/A AMPE(E) is being installed in a location that has an I-S/A AMPE. Those modules necessary to upgrade the system to its enhanced version must be loaded/configured without shutting down the system. This is in keeping with continuity of service and user transparency objectives.

(5) I-S/A AMPE(E) Site Selection. Cutover transition considerations that should be applied in selecting sites to receive the ASC replacements are discussed in the following subparagraphs.

Local Service. All I-S/A AMPE(E)s will be deployed as AMPE replacements and/or I-S/A AMPE upgrades and will reside functionally in the access area. They will be dual connected to the PSN backbone using the Mode VI Host interface. I-S/A AMPE(E)s should be strategically placed to minimize transmission costs by taking advantage of the local service implications of the access node and the direct homing potential for nearby AMPEs and I-S/A AMPEs.

Facilities. Since the I-S/A AMPE(E) is of greater importance than the I-S/A AMPE to the network, it is envisioned that it will require additional support in the form of an uninterruptible power source (UPS) and a backup power plant. Thus consideration should be given to former ASC sites since these sites generally possess the needed power facilities as well as other necessary facilities, e.g., a patch-and-test facility (P&TF).

Survivability. Since enhanced system survivability is a system goal, extra consideration should be accorded to facilities with unique survivability provisions (e.g., hardening, uniterruptable power supply).

Expandability. The primary purpose for initial I-S/A AMPE(E) installations is to facilitate ASC phaseout. Consequently, the primary emphasis during planning stages will be to identify those I-S/A AMPE(E) sites that will permit ASC closings. Future requirements for I-S/A AMPE(E) service can be addressed later, since these needs can be satisfied by upgrading existing I-S/A AMPE sites.

e. New Services. As currently projected, requirements for new network services, such as mailbox and teleconferencing, will be satisfied through modular expansion of the I-S/A AMPE(E). Each new service will be test marketed by introducing it initially to a limited number of subscribers on a pilot demonstration basis using R&D funds. The first of these pilot demonstrations is not anticipated before 1985.

The modular implementation of these services offers a great deal of flexibility in configuring I-S/A AMPE(E)s to provide these services. As an extreme, these modules could conceivably be configured in a network component other than an I-S/A AMPE(E) (e.g., to provide backup capability). Requirements for these modules will be evaluated on a case-by-case basis.

5. EXPANSION OF PACKET SWITCH NODE (PSN) BACKBONE

The Mid-Term IAS will mark the emergence of a worldwide data backbone. PSNs will be deployed in both CONUS and overseas to augment the near-term 8 node network. As the data backbone evolves, transition objectives and issues take on the following significance.

a. PSN Expansion - Sequence of Events. As stated previously, it is undesirable to execute a transition step that will be reversed by subsequent transition steps. In this regard, each step of the transition should reflect as closely as possible the final Mid-Term configuration. In this context, requirements for PSNs must be identified during planning stages through consideration of the deployment of other Mid-Term network components, specifically, the I-S/A AMPE, I-S/A AMPE(E) and CFT. The installation of PSNs should be closely coordinated with the schedules for the other components so that PSNs are fielded first. This will facilitate a smooth transition by eliminating needless iterative rehoming of subscriber equipment and access nodes. Rehoming is unavoidable in an evolving network; but, it can be kept to a minimum through careful transition planning.

b. Overseas PSN Implications. As enhanced survivability is a system objective, consideration should be given to deploying smaller, more mobile PSNs overseas. Implementation of the PSN TAC (Terminal Access Control) functions in the I-S/A AMPEs should facilitate a smaller PSN configuration.

6. INTRODUCTION OF THE COMMON FAMILY OF SUBSCRIBER TERMINALS

The Mid-Term IAS will be required to support a mix of subscriber terminals that fall into one of the following generic categories:

- AUTODIN I Terminals
- AUTODIN II Terminals
- AUTODIN II Hosts
- Common Family AUTODIN Terminals (CFT)

As the IAS evolves, the distinction between these different categories of terminals will disappear as the CFT will satisfy all subscriber requirements. Beginning in 1984, the CFT will be used exclusively to fulfill needs for new or replacement subscriber equipment. Exceptions to this policy will be evaluated on a case-by-case basis.

All categories of equipments are expected to exist through the Mid-Term. Depending on the service needs of the subscriber, terminals will be terminated on AMPEs, I-S/A AMPEs, I-S/A AMPE(E)s, or PSNs. Table XV shows the termination alternatives available to a subscriber. Also, with the I-S/A AMPE(E) located functionally in the access area, dual homing may be employed for those programmable terminals capable of selecting the best path relative to the service desired. Such terminals would be dual homed to a PSN and an I-S/A AMPE(E).

7. INTEGRATION OF SECURITY COMPONENTS

The Mid-Term IAS will feature the introduction of an end-to-end encryption (E3) capability. This capability will be based on the use of BLACKER hardware and software components. Transition considerations for these elements are provided in a separate classified appendix (Appendix B).

8. MILESTONES AND SCHEDULE

The overall strategy for transitioning from the Near-Term to the Mid-Term IAS can be postulated in terms of a sequence of events, target dates, and the interdependencies of events. The transition considerations discussed in the preceding paragraphs have been factored into a recommended transition plan as shown in Table XVI and Figure 23. Table XVI lists the required activities and their associated target dates in chronological order. Figure 23 presents these activities as a milestone chart to help visualize their interdependencies.

Although the ultimate transition strategy may deviate slightly from what is postulated, the recommended approach does, in fact, demonstrate the feasibility of achieving the Mid-Term IAS in a deliberate and continuous manner. It also provides the framework for subsequent, more detailed network element transition plans.

TABLE XV. MID-TERM IAS TERMINATION POLICY

		TERMINATING DEVICE			
NETWORK COMPONENT		AMPE	PSN	I-S/A AMPE	I-S/A AMPE(E)
TERMINAL	AUTODIN I	YES	YES[1]	YES	YES
	AUTODIN II	NO	YES	YES	YES
	AUTODIN II (HOST)	NO	YES	NO	NO
	COMMON FAMILY OF TERMINALS	NO	YES	YES	YES

1. MODE I ONLY (TERMINATED ON PSN BUT "HOMED" TO I-S/A AMPE(E)).

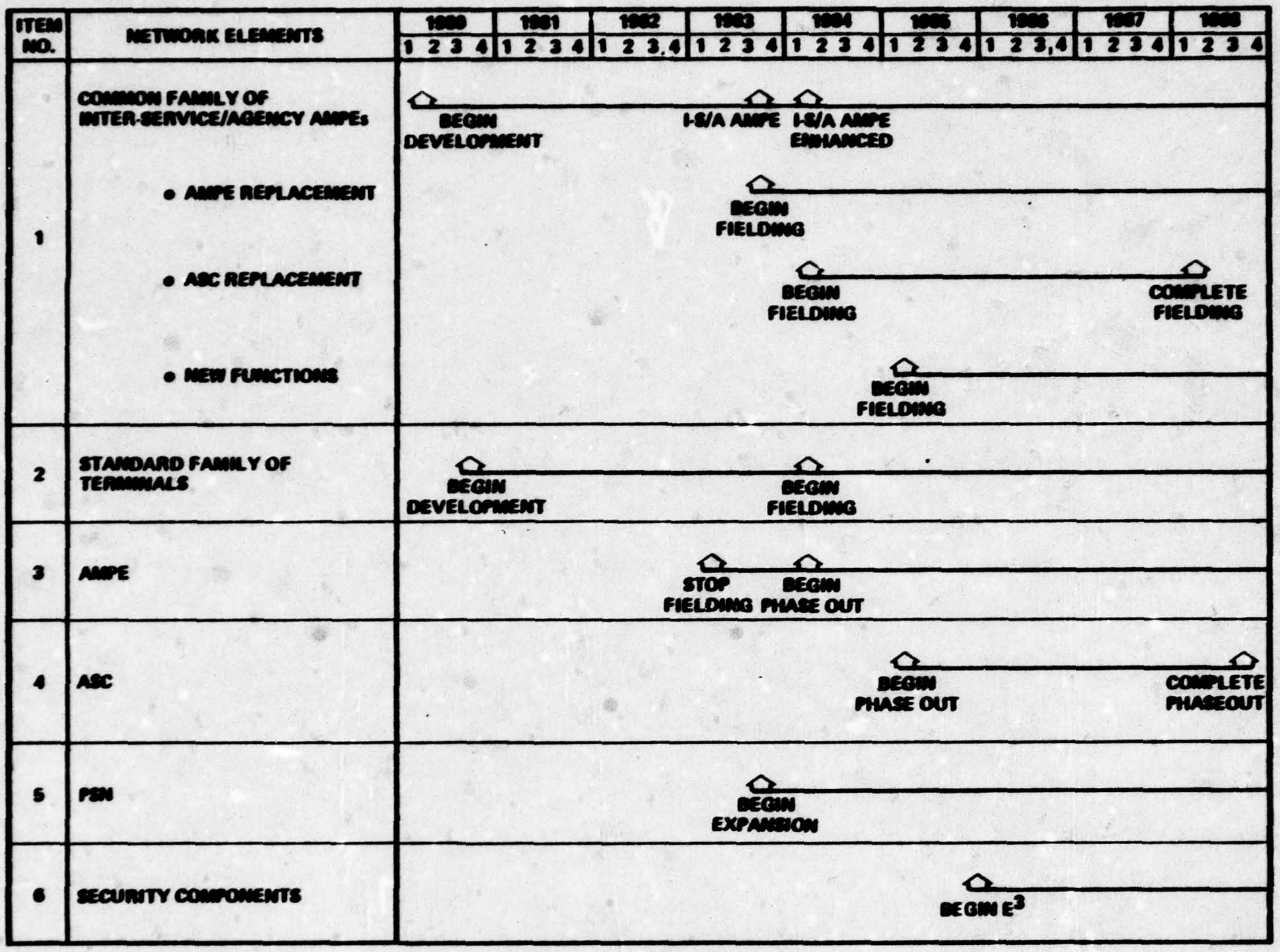


Figure 23. Mid-Term IAS Milestones

TABLE XVI. MID-TERM IAS TRANSITION PLAN

Activity	CY Target Date
a. Start Development of I-S/A AMPE Family of Nodes	1979
b. Start Development of Common User Family of Terminals	1979
c. Start Mid-Term Topology Design & Related Studies	1979
d. Start Development of New Services and Functions	1980
e. Detailed Definition of Functions for I-S/A AMPE	1980
f. HOL Decision (DoD)	1981
g. Begin development of HOL Software for I-S/A AMPE	1981
h. Mid-Term IAS System Implementation Plan Development	1981
i. Definition of Services and Functions for I-S/A AMPE(E)	1982
j. Begin PSN Expansion (O/S and CONUS as required)	1984
k. Stop Fielding Near-Term I-S/A AMPE	1984
l. Begin Fielding I-S/A AMPE (AMPE Replacement)	1984
m. Begin Fielding Common Family of Terminals	1984
n. Begin AMPE Phaseout	1984
o. Begin Fielding I-S/A AMPE(E)	1985
p. Begin Phaseout of Remaining ASCs	1985
q. Begin Fielding End-to-End Encryption Equipment	1986
r. Complete Phaseout of O/S ASCs	1987
s. Complete Fielding I-S/A (AMPE)(E)	1988

TABLE XVI. MID-TERM IAS TRANSITION PLAN (Continued)

t.	Complete Phaseout of CONUS ASCs	1988
u.	Complete a Worldwide PSN Backbone	1988
v.	Mid-Term IAS Architecture Achieved	1988
w.	Complete AMPE Phaseout	1990

REFERENCES

a. DCA, Integrated AUTODIN System Architecture, December 1977.

b. DCA, System Performance Specification (Type "A") for AUTODIN II Phase I, January 1977 Revision.

c. ASD C3I Memorandum, Integrated AUTODIN System Architecture Report, 11 October 1978.

d. DCEC, A Preliminary IAS Requirements Definition, October 1977.

e. DCEC, AUTODIN II Data Base, December 1977.

f. TRI-TAC ICD 004, TCCF Report and Directive Message Protocols, 1978 Revision.

g. DCAC 600-60-1, DCA Cost and Planning Factors Manual, 21 February 1978 Revision.

h. DCEC Technical Note 17-77, Architectural Directions for an Integrated AUTODIN System, December 1977.

APPENDIX A

AMPE AND INTER-SERVICE/AGENCY AMPE POPULATION FOR 1982-1990

I. INTRODUCTION

This analysis was performed in order to define the projected requirements for the Inter-Service/Agency Automated Message Processing Exchange (I-S/A AMPE) as an input to the definition of the Mid-Term Architecture for the Integrated AUTODIN System (IAS). The analysis includes definition of the current and projected Automated Message Exchange (AMPE) population through the mid-term and development of a postulated replacement strategy. The actual I-S/A AMPE-for-AMPE replacement strategy and I-S/A AMPE requirements will be defined by DCA in coordination with the AMPE and potential I-S/A AMPE users. This analysis and the projections presented here are intended for planning purposes only.

II. ASSUMPTIONS

The assumptions that form the basis for the following analysis are:

1. A standardized AMPE for inter-service/agency use will be available by the end of 1981 for deployment beginning in 1982. This Near Term Inter-Service/Agency AMPE will be developed by a lead MILDEP (most likely Air Force), primarily to meet near-term needs of the Air Force and Defense Logistics Agency.

2. The Inter-Service/Agency AMPE defined by the IAS Mid-Term Architecture will be available for deployment in the 1984 time frame. Some overlap with deployment of the Near-Term I-S/A AMPEs may occur.

3. The current projected AMPE population by 1983 will be 114, broken down as follows:

Service/Agency	Number of AMPEs
Navy	22
Army	20
Air Force	22
NSA	31
DLA	19
TOTAL	114

The analysis assumes that Army and Navy projected AMPE installations for the remainder of the near-term (through 1982) will proceed as planned. Air Force projected AMPE installations for 1981 will be delayed and, together with the projected installations for 1982, be satisfied by Near-Term I-S/A AMPEs commencing in 1982.

4. Existing DLA AMPEs (fielded in the early 1970s) will all be replaced between 1982 and 1984.

5. The service life of all current AMPEs is 8 to 10 years. Although many AMPEs are able to remain in place longer, the 8 to 10 year figure commonly used for economic analyses is used as a worst case.

6. AMPE requirements identified for the period 1978-1982 indicate a growth in AMPE population of 8% to 9% per year. This rate of growth in the number of AMPEs is not expected to continue beyond 1982 for two reasons, however. First, the Near-Term I-S/A AMPE that meets multi-user requirements will be available. Secondly, a substantial number of AMPE sites will exist as a result of near-term installation growth. In the post-1982 period, therefore, it will become increasingly likely that new subscriber requirements can be satisfied through use of existing AMPEs or I-S/A AMPEs rather than through new system installations. A reduced rate of growth (4%) was, therefore, used for projecting the I-S/A AMPE population beyond 1982. Demand for new systems beyond the near-term is assumed at a four percent growth rate per year. It was further assumed that one percent will be absorbed through consolidation of existing I-S/A AMPEs. The remaining three percent will be satisfied by new I-S/A AMPE installations.

7. All NSA STREAMLINERs will be replaced between 1985 and 1987, based on their actual fielding dates (1977-1978) and assumed service life (Assumption 5). The location of five STREAMLINER systems was unavailable in time for inclusion in this analysis. A one-for-one replacement of these five systems is assumed.

8. LDMX-I systems (single 70/45 processor) fielded during the remainder of the near-term, as the result of NAVCOMPARS-I systems (dual 70/45 processors) being replaced by NAVCOMPARS-IIs, will be replaced in the 1985-1987 time frame based on the 8 to 10 year service life of the hardware.

9. CONUS AMPEs within 50 miles of each other will be replaced by a single I-S/A AMPE or by two I-S/A AMPEs if more than three AMPEs are involved. Otherwise I-S/A AMPE for AMPE replacement will be on a one-for-one basis in CONUS.

10. Overseas AMPEs that are colocated will be replaced by a single I-S/A AMPE or by two I-S/A AMPEs if more than two AMPEs are involved. Otherwise I-S/A AMPE-for-AMPE replacement will be on a one-for-one basis overseas.

11. AMPE testbed facilities will remain in place as long as any AMPEs of the corresponding Service or Agency are still in the field. Furthermore, testbed facilities will not be replaced with I-S/A AMPEs nor will they be counted in any CONUS AMPE consolidation as described by Assumption 9.

III. ANALYSIS

A total of 114 AMPEs are currently projected to be in place by the end of 1982, thirty-one of which are NSA STREAMLINER systems. An analysis of the AMPEs was performed on a case-by-case basis from which replacement dates and consolidation strategies were developed using the assumptions listed in Section II. The results of the analysis are presented in Table A-I. The 83 projected AMPEs belonging to Army, Navy, Air Force, and DLA are listed by geographic location. Also shown is the time frame in which each AMPE will require replacement and consolidation strategy. Additional notes related to Table A-I are:

- STREAMLINER locations are CONFIDENTIAL and are therefore not listed
- Army AMPEs that are not already in place have the projected installation date listed along with the location name
- Navy AMPEs are identified by system type (LDMX or NAVCOMPARS) and generation (I or II). Those that are not yet in place have the projected installation date listed as well.
- Eleven (11) of the Air Force AMPE locations are labeled "NEW". These represent 1982 and delayed 1981 requirements (Assumption 3) that will be satisfied by I-S/A AMPEs rather than the current ATP 5/6 program. Seven of the requirements are met by five new I-S/A AMPEs installed specifically to meet those requirements. The remaining four requirements are met via consolidation on I-S/A AMPEs installed to replace one Navy and three DLA locations.

The population of AMPEs and I-S/A AMPEs through the Mid-Term and into the Far-Term IAS can be derived from Table A-I. These figures are shown numerically in Table A-II and graphically in Figure A-1. Although NSA AMPE locations are not listed in Table A-I, an analysis of the 26 known locations indicated that eight sites could potentially be consolidated with other Inter-Service/ Agency AMPEs. The remaining 18 sites plus the five sites that

TABLE A-I. PROJECTED AMPE AND I-S/A AMPE POPULATION, BY LOCATION

ID	I-S/A AMPE LOCATION	REPLACED AMPE	OWNED BY	PROJECTED REPLACEMENT DATE	NO. OF I-S/A AMPEs
1	Alabama, Huntsville	Huntsville	A	85-87	1
2	Arizona, Sierra Vista	Ft. Huachuca	A	88-90	0 (Test Bed)
3	California, Los Angeles	Los Angeles	DLA	82-84	1
4	Oakland	Oakland	A	82-84	1
5	Sacramento	Sacramento (1980)	A	88-90	
		McClellan AFB (New)	AF	82-84	1
		Travis AFB (New)	AF	82-84	
6	San Diego	San Diego (LDMX-1)	N	82-84	1
		North Island (LDMX-1, 1979)	N	85-87	
7	Stockton	Stockton (NCP-II)	N	88-90	1
		Tracy	DLA *	82-84	
8	Colorado, Colorado Springs	Ent AFB	AF	88-90	1
9	Denver	Lowry AFB	AF	88-90	1
10	England, London	London (LDMX-II)	N	88-90	1
11	Europe, Unknown	Unknown (1981)	A	88-90	1
12	Florida, Jacksonville	Jacksonville(LDMX-I, 1981)	N	85-87	1
13	Tampa	MacDill AFB	AF	88-90	1
14	Valparaiso	Eglin AFB (New)	AF	82-84	1

TABLE A-I. PROJECTED AMPE AND I-S/A AMPE POPULATION, BY LOCATION (Continued)

15	Georgia, Atlanta	Atlanta	A	88-90	1
		Atlanta	DLA	82-84	
16	Macon	Robins AFB (New)	AF	82-84	1
17	Germany, Frankfurt	Frankfurt (1980)	A	88-90	1
18	Heidelburg	Heidelburg (1978)	A	85-87	1
19	Stuttgart	Stuttgart (1980)	A	88-90	1
20	Ramstein AB	Ramstein AB	AF	88-90	1
21	Guam	Guam (NCP-II, 1979)	N	88-90	1
22	Hawaii, Oahu	Camp Smith (LDMX-I)	N	85-87	2
		Hickam AFB	AF	88-90	
		Honolulu (NCP-II, 1979)	N	88-90	
		Makalopa (LDMX-I)	N	85-87	
23	Illinois, Chicago	Chicago	DLA	82-84	1
24	Rock Island	Rock Island (1980)	A	88-90	1
25	Japan, Yokota	Yokota	AF	88-90	1
26	Yotuska	Yotuska (LDMX-I, 1981)	N	85-87	1
27	Italy, Naples	Naples (NCP-II, 1981)	N	88-90	1
28	Kansas, Kansas City	Ft. Leavenworth (1981)	A	88-90	1
29	Korea, Taegu	Taegu	A	85-87	1

TABLE A-I. PROJECTED AMPE AND I-S/A AMPE POPULATION, BY LOCATION (Continued)

30	Louisiana, New Orleans	New Orleans (LDMX-I, 1982)	N	85-87	1
31	Maryland, Baltimore	Baltimore	A	85-87	1
32	Massachusetts, Boston	Boston	DLA	82-84	1
33	Michigan, Battle Creek	Battle Creek	DLA	82-84	1
34	Missouri, St. Louis	St. Louis (1980)	A	88-90	
		St. Louis	DLA	82-84	1
		Scott AFB, Ill. (1979)	AF	88-90	
35	Nebraska, Omaha	Offutt AFB (1979)	AF	88-90	1
36	New Jersey, Ft. Monmouth	Ft. Monmouth (1979)	A	88-90	
		McGuire AFB (New)	AF	82-84	1
		New York City, N.Y.	DLA	82-84	
37	North Carolina, Camp Lejeune	Camp Lejeune (LDMX-I, 1980)	N	85-87	1
38	Ohio, Dayton	Wright-Patterson AFB (New)	AF	82-84	1
		Gentile	DLA	82-84	
39	Cleveland	Cleveland	DLA	82-84	1
40	Columbus	Columbus	DLA	82-84	1
41	Oklahoma, Oklahoma City	Tinker AFB (Test Bed)	AF	88-90	0 (Test Bed)
42	Oklahoma City	Tinker AFB (New)	AF	82-84	1

TABLE A-I. PROJECTED AMPE AND I-S/A AMPE POPULATION, BY LOCATION (Continued)

43	Pennsylvania, Carlisle	Carlisle Barracks (1979)	A	88-90	
		Letterkenny	A	85-87	1
		Mechanicsburg	DLA	82-84	
44	Philadelphia	N. Philadelphia	DLA	82-84	1
		S. Philadelphia	DLA	82-84	
45	Philippines	Clark AFB	AF	85-87	1
46	South Carolina, Charleston	Charleston (LDMX-I, 1980)	N	85-87	1
47	Tennessee, Memphis	Memphis	DLA	82-84	1
48	Texas, Dallas	Dallas	DLA	82-84	1
49	San Antonio	Kelly AFB (New)	AF	82-84	1
		Randolph AFB (New)	AF	82-84	
50	El Paso	Ft. Bliss (1981)	A	88-90	1
51	Utah, Ogden	Ogden	DLA	82-84	1
		Hill AFB (New)	AF	82-84	
52	Virginia, Norfolk	Breezy Point (LDMX-II, 1982)	N	88-90	
		Hampton Roads (LDMX-I)	N	82-84	2
		Langley AFB (New)	AF	82-84	
		LANT (NCP-II, 1980)	N	88-90	
53	Richmond	Richmond	DLA	82-84	1

TABLE A-I. PROJECTED AMPE AND I-S/A AMPE POPULATION, BY LOCATION (Continued)

54	Washington, Puget Sound	Puget Sound (LDMX-I, 1979)	N	85-87	1
55	Washington, D.C.	Cheltanham, Maryland (Test Bed)	N	88-90	0 (Test Bed)
		Navy Yard (Test Bed)	N	88-90	0 (Test Bed)
		Alexandria, Virginia (1981)	A	88-90	
		Baileys Crossroads, Virginia	A	85-87	
		Cameron Station, Virginia	DLA	82-84	3
		Crystal Plaza, Virginia (LDMX-I)	N	82-84	
		Pentagon (LDMX-I)	N	85-87	
		Pentagon	AF	88-90	

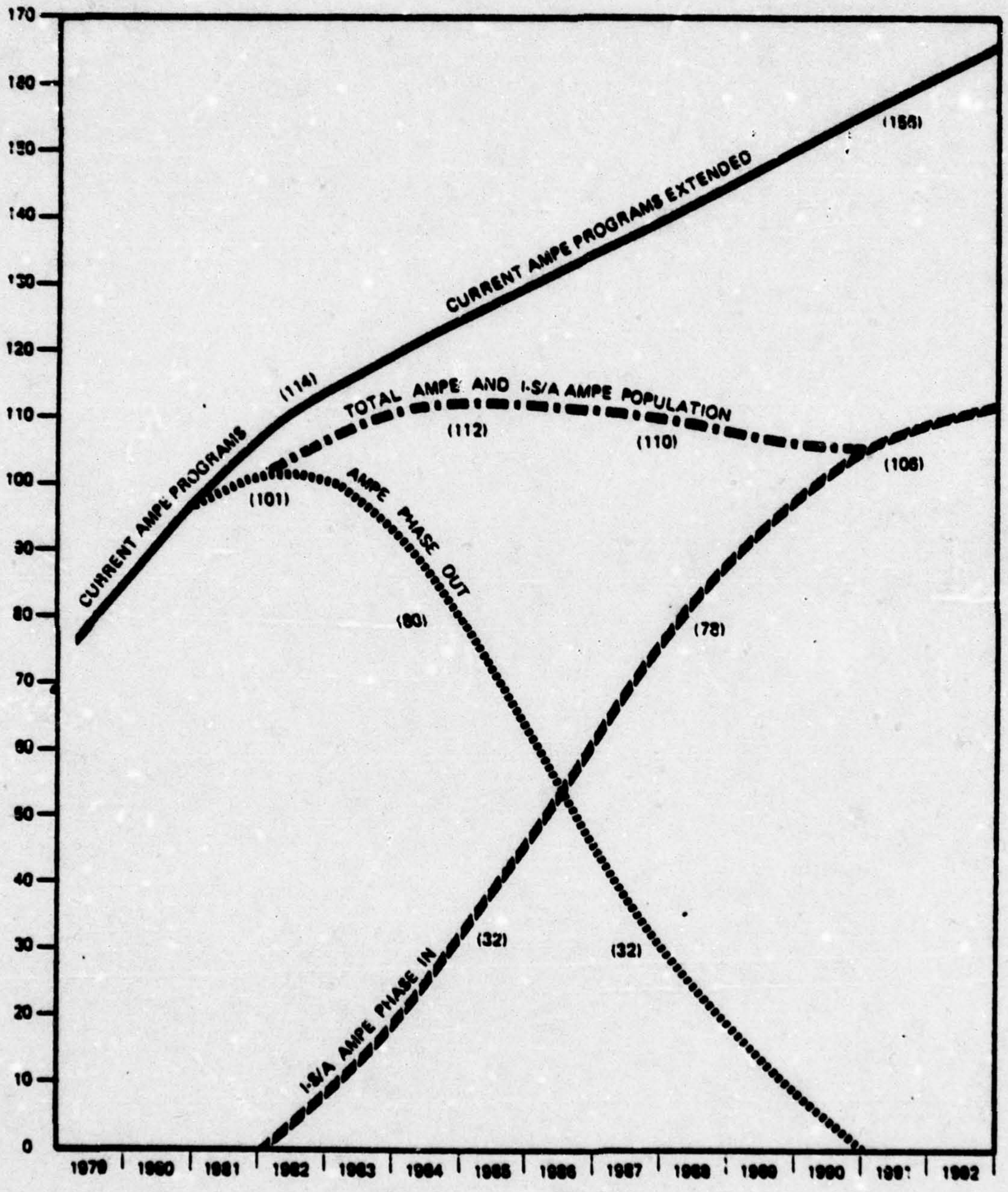


Figure A-1. Projected AMPE & I-S/A AMPE Population

could not be identified (Assumption 7) yielded 23 replacement I-S/A AMPEs. These have been included in the net increase of 36 replacement I-S/A AMPEs shown for the 1985-1987 time frame in Table A-II.

IV. CONCLUSIONS

Without the I-S/A AMPE program and consolidation of AMPE sites, the number of AMPEs could be expected to exceed 150 by 1990 based on the projected rate of growth. The I-S/A AMPE program, with 106 I-S/A AMPEs in 1990, represents a potential 23% savings in the number of elements.

TABLE A-II. PROJECTED AMPE AND I-S/A AMPE POPULATIONS, BY SERVICE/AGENCY

Number of AMPEs	1981	(Change)	1984	(Change)	1987	(Change)	1990
NAVY	20	-3	19*	-10	9	-9	0
AMRY	20	-1	19	-6	13	-13	0
AIR FORCE	11	0	11	-1	10	-10	0
NSA	31	0	31	-31	0	0	0
DLA	19	-19	0	0	0	0	0
Total AMPEs	101	-23	80*	-48	32	-32	0
Replacement I-S/A AMPEs	0	+21	21	+36	57	+18	75
New I-S/A AMPEs	0	+11	11	+10	21	+10	31
Total I-S/A AMPEs	0	+32	32	+46	78	+28	106
Total AMPEs & I-S/A AMPEs	101	+9	112*	-2	110	-4	106

*Two LDMX installations are projected for 1982
Thus: 20 + 2 LDMXs -3 replacements = 19

APPENDIX B

MID-TERM IASA TRAFFIC FLOW ANALYSIS

APPENDIX B
MID-TERM IAS TRAFFIC FLOW ANALYSIS

1. INTRODUCTION

This appendix describes a traffic flow analysis performed as part of the Mid-Term Integrated AUTODIN System (IAS) architecture definition effort.

The primary purpose of the traffic flow analysis is to provide quantitative results in support of the cost analysis and technical factors analysis. In most cases, therefore, the numerical results of this analysis are used as direct inputs to subsequent analyses. In addition, all phases of the evaluation process draw upon qualitative assessments and insights derived from this analysis. However, the evaluation of alternatives based directly on traffic flow considerations is not intended.

The specific objectives of this analysis are:

- Determine the probable traffic flow characteristics of alternative architectures
- Estimate the size of communications facilities required to support alternative architectures
- Estimate the communications handling capability of the postulated nodal elements required to support each architecture

The primary purpose of the Mid-Term IAS definition effort is to evaluate alternatives and select a preferred architecture for the Mid-Term. Therefore, in order to simplify the computational effort the traffic flow analysis was performed on a comparative basis, concentrating on those areas of traffic flow that represent a significant difference among alternatives. Thus, traffic categories which represent a minor contribution to total traffic flow, or which are common to all three candidates, are not specifically addressed in the detailed analysis.

The basic approach to the traffic flow analysis consists of the following steps:

- Development of a baseline network model. A network configuration is selected, consisting of the backbone and portions of the access area which are architecture dependent (from a traffic flow standpoint). The model is described by means of nominal parameter values consistent with current mid-term projections.

- Development of a baseline traffic model. Major architecture-dependent traffic categories are identified, and their flow through the network is described. Nominal values are specified for input traffic volumes and traffic flow parameters, based upon projected traffic statistics and an understanding of the operating environment.

- Formulation of traffic flow equations. For each traffic category a set of expressions is developed for calculating nodal and link traffic flows.

- Traffic computation. The various traffic expressions are incorporated into a set of equations which are programmed on a commercial computing service to calculate aggregate nodal and link traffic flows for each architecture. The computations use nominal (baseline) values for network parameters and input traffic volumes.

- Sensitivity analysis. The impact of changes in assumptions and parameter values on the traffic results is explored.

A more detailed description of the approach and a summary of the results are presented in the following paragraphs.

2. ASSUMPTIONS AND GROUND RULES

The traffic flow analysis is based upon the requirements and projected environment for the mid-term time frame defined in Section II of the body of this report. The alternative architectures evaluated under this analysis are described in Section III.

a. Baseline Network Model. The network model used in the analysis is defined by the following assumptions and guidelines:

- The basic PSN backbone, which is common to all alternative architectures, was simplified in a manner which facilitated the analysis. However, in order to provide some insight into the probable performance of the eventual IAS network, as well as to promote consistency with other analyses, the critical characteristics of the assumed backbone network were designed as closely as possible to match those of a representative backbone network. Specifically the backbone network model used to calculate traffic flows is shown in Figure B-1. The convenient feature of this model is its uniformity - each PSN is connected to four other PSNs in a regular topology. In all major respects (number of PSNs, average number of users per PSN, average distance between PSNs, average number of trunks per PSN) it is identical to a representative AUTODIN II architecture described in the System Performance Specification for AUTODIN II, Phase I, January 1977 revision.

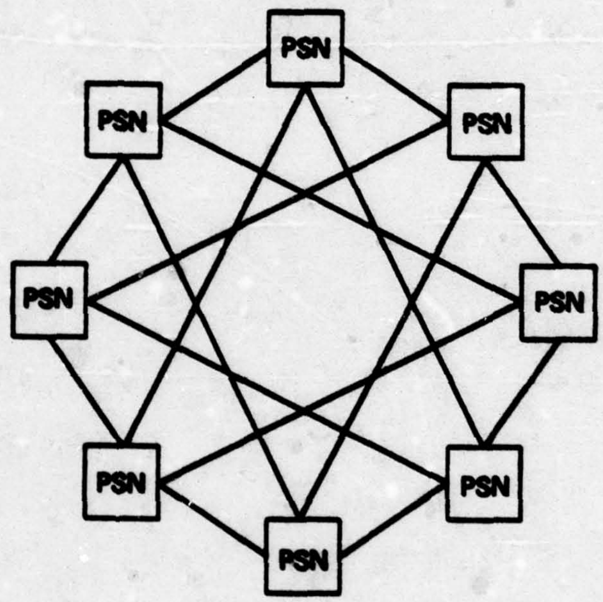


Figure B-1. Baseline Backbone Network Connectivity

- Each PSN has associated with it an access area, consisting of subscribers and network elements. For the purpose of this analysis, the same uniform configuration (in terms of subscriber population and connectivity) was assumed for each access area.

- The calculation of traffic flows assumes that:

  - subscribers are singly connected to a nodal element

  - I-S/A AMPEs are singly connected to a PSN or to an I-S/A AMPE(E)

  - I-S/A AMPE(E)s (if any) are singly connected to a PSN

  - CSFs (if any) are singly connected to a PSN

  The effect of dually connecting some of these elements is explored in the sensitivity analysis.

- The network model is a representation of the projected 1988 CONUS configuration. The traffic flow characteristics, however, are expected to be relatively constant throughout the global system during the time frame of interest.

Nominal values for the principal network and subscriber configuration parameters are presented in Table B-I for each architecture. The sensitivity of the traffic results to deviations from these nominal values is discussed later in the appendix.

b. Baseline Traffic Model. The input traffic assumptions used in this analysis were based upon the numbers and types of users, projected terminal populations, projected AMPE and I-S/A AMPE populations, and the postulated services and functions that will be provided by the Mid-Term IAS. These issues are described in greater detail in Section II of the body of the report.

Consistent with the comparative nature of this analysis, traffic types which do not have a significant impact on the evaluation of alternatives have been excluded. The 1988 estimates for AUTODIN I and AUTODIN II average busy hour traffic (Subsection II-4) provide the starting point in the identification of appropriate traffic types.

As a result of preliminary analysis, it was determined that the 1988 estimates for interactive and query/response traffic represent a relatively minor contribution to total IAS traffic (less than 5 percent), and thus were excluded from the analysis. It was also determined that the flow of AUTODIN II bulk data traffic is virtually identical in the three alternative architectures, and, therefore, not necessary for a comparative evaluation. (Because of its substantial volume, however, bulk traffic was factored into the subsequent analysis of transmission cost.)

TABLE B-I. BASELINE NETWORK PARAMETERS

PARAMETER \ ARCHITECTURE	I	II	III
NUMBER OF PSNs	8	8	8
NUMBER OF CSFs	1-8	0	1-8
NUMBER OF I-S/A AMPE(E)s	0	1-8	1-8
NUMBER OF I-S/A AMPEs[(1)]	70	62-69[(2)]	62-69[(2)]
NUMBER OF TERMINALS	1200 DIN I 1800 DIN II	1200 DIN I 1800 DIN II	1200 DIN I 1800 DIN II
FRACTION OF I-S/A AMPEs DIRECTLY CONNECTED TO A PSN	30%	30%	30%
NUMBER OF PSN-PSN LINKS INCIDENT ON A PSN	4	4	4

[(1)] This number is based on a preliminary projection of I-S/A AMPE population; see Appendix A for latest estimates.
[(2)] The analysis assumes that the total number of I-S/A AMPEs plus I-S/A AMPE(E)s is constant.

Consequently, the traffic flow analysis focused on narrative/record (N/R) traffic from both AUTODIN I-type and AUTODIN II-type subscribers. For the purpose of the analysis, an AUTODIN I-type subscriber is defined as a message oriented user with terminal equipment (including AMPEs) which will support only AUTODIN I type operation. An AUTODIN II-type subscriber is defined as an ADP oriented user with terminal equipment that will support AUTODIN II type operation. These definitions (introduced in Subsection III-2-f of the report) are used only for the purpose of modeling the existing subscriber characteristics related to traffic flow. As the IAS evolves through the mid-term, it is anticipated that such distinctions will no longer be required.

The IAS traffic is also classified according to its destination - local or remote. For the purpose of this analysis, local is defined to mean "served by the same PSN". The baseline traffic model assumes that 25 percent of the input traffic is sent to local subscribers.

In addition to subscriber type and traffic destination, the services provided by the network are important factors in the characterization of traffic flow among nodal elements. Consideration of the Mid-Term IAS services and functions led to the definition of six basic categories of narrative/record traffic, selected for use in the traffic flow analysis:

- Single Address Messages
- Multiple Address Messages
- Teleconferencing
- Gateway
- Mailbox
- AUTODIN II traffic requiring no service element support

Average input traffic values for each category are presented in Table B-II, for AUTODIN I and AUTODIN II subscribers. The modeling of these categories is discussed in the following section.

Additional assumptions which characterize the baseline traffic model are the following:

- The nodal (or network) elements of interest in this analysis are the Packet Switched Node (PSN), the Central Service Facility (CSF), and the Enhanced Inter-Service/Agency AMPE (I-S/A AMPE(E)). Since the basic I-S/A AMPE is common to all three alternative architectures, it was treated as a source of traffic input for the purpose of this analysis. The CSF and the I-S/A AMPE(E) are the candidate service elements for the mid-term IAS.

TABLE B-II. AVERAGE 1988 INPUT TRAFFIC ESTIMATES (BUSY HOUR)

TRAFFIC CATEGORY	AUTODIN I		AUTODIN II	
	Input Rate [Kbps]	Fraction of Total	Input Rate [Kbps]	Fraction of Total
• SINGLE-ADDRESS MESSAGES	213.8	64%	18.1	15%
• MULTIPLE-ADDRESS MESSAGES	70.1	21%	6.1	5%
• TELECONFERENCING	16.7	5%	12.1	10%
• GATEWAY	16.7	5%	6.1	5%
• MAILBOX	16.7	5%	18.1	15%
• AUTODIN II TRAFFIC REQUIRING NO SERVICE ELEMENT SUPPORT	–	0%	60.5	50%
TOTAL	334.0	100%	121.0	100%

- The links of interest in the traffic flow calculations are:

  - PSN - PSN
  - PSN - CSF (Architecture I and III)
  - PSN - I-S/A AMPE(E) (Architecture II and III)
  - PSN - I-S/A AMPE
  - I-S/A AMPE(E) - I-S/A AMPE (Architecture II and III)

- In order to simplify the traffic calculations certain "uniformity" assumptions have been made. In particular, the PSNs are modeled identically, regardless of how many CSFs and I-S/A AMPE(E)s the network actually contains (unless, of course, there are none). By the same concept, traffic in the backbone is assumed to be distributed uniformly over all PSN-PSN links. These simplifying assumptions should not diminish the significance of the results, since the analysis concentrates on average (i.e., global) traffic flow behavior in the network.

- The fraction of traffic generated by subscribers terminated on I-S/A AMPEs assumed a nominal value of 87.2 percent (average over all six traffic categories and subscriber types).

- Certain traffic categories involve the delivery of a message or transaction to multiple destinations. This "traffic expansion" is accomplished at a service element. The nominal average expansion factors used in the analysis are:

  - for Multiple Address Message Transfer: 7
  - for Teleconferencing: 2.5
  - for Mailbox: 2.5

- All traffic flows in this analysis are based on 1988 projections for busy hour traffic.

The sensitivity of the traffic flow results to changes in the baseline traffic parameters is addressed in the following section.

3. TRAFFIC CALCULATIONS

The baseline network and traffic models described above constitute the basis for the formulation of traffic flow equations. These equations describe, for each alternative architecture, the movement of data from source to destination via intermediate links and nodal elements. The flow of traffic is a function of: the type of traffic (and hence the services/functions required from nodal elements); the type of subscriber at the source; and the type and location of the subscriber at the destination.

a. Nodal Element Traffic. Source-to-destination flows have been postulated for each traffic category in order to develop the necessary equations. These flows are not intended to be exact representations of IAS traffic. Rather, they are simplifications, defined for the purpose of this analysis, which model conservative or "worst-case" traffic patterns. Their purpose is to illustrate the basic behavior of traffic in the network. A brief description of the modeling of the six defined traffic categories (introduced in Table B-II) follows.

- Single-Address Message Traffic - in general, this is modeled as single-address traffic that travels from source to destination via an intermediate processing node. For AUTODIN I-type subscribers directly connected to an I-S/A AMPE the intermediate processing is assumed to occur at the I-S/A AMPE. For all other subscriber types and connections, traffic is assumed to flow to the nearest service element (CSF in Alternative I, I-S/A AMPE(E) in Alternatives II and III) before proceeding to its destination.

- Multiple-Address Message Traffic - modeled as multiple-address traffic with an average of seven addressees (baseline value). The model assumes that this traffic travels from its source to the nearest service element (CSF in Alternative I, I-S/A AMPE(E) in Alternatives II and III), from which the message is transmitted seven times to different destinations. This simplified model does not portray the actual flow of Multiple-Address traffic in the AUTODIN system. However, the disparity between the model and the actual flow can be simply translated into a difference in the number of addressees. The sensitivity analysis explores the variation in this parameter, and indicates that the comparative results among alternatives are insensitive to the number of addressees.

- Teleconferencing Traffic - modeled in a similar manner to Multiple-Address traffic, but with an average of 2.5 addresses (baseline value). The model assumes a flow from source to the nearest service element (CSF in Alternatives I and III, I-S/A AMPE(E) in Alternative II), from which multiple copies are sent to their destinations.

- Gateway Traffic - modeled as single-address traffic that flows from an IAS source to the nearest service element (CSF in Alternatives I and III, I-S/A AMPE(E) in Alternative II), and then to an external destination; or from an external source to the nearest service element and then to an IAS destination. It is assumed that an equal amount of traffic flows into and out of the network.

- Mailbox Traffic - modeled as multiple-address traffic that travels (as a single copy) from the source to the nearest service element (CSF in Alternative I, I-S/A AMPE(E) in Alternatives II and III), from which it is transmitted to M other service elements (M is a function of the number of service elements, the average number of addressees, and whether the destinations are local or remote). On the average, a total of 2.5 copies of the message (baseline value) are then transmitted from the service elements to the appropriate destinations.

- AUTODIN II Traffic requiring no service element support - modeled as single-address traffic transmitted from one AUTODIN II subscriber to another, without the need for intermediate processing at a service element.

The basic nodal traffic flows for the three IAS architectures are defined by the following rules:

- the PSN input consists of traffic from CSFs (in Alternatives I and III), I-S/A AMPE(E)s (Alternatives II and III), other PSNs, and its community of users (i.e., subscribers connected directly to the PSN or indirectly via an AMPE or I-S/A AMPE).

- the CSF (Alternatives I and III) exchanges traffic only with the PSN to which it is connected and with external subscribers via a gateway.

- an I-S/A AMPE(E) (Alternatives II and III) exchanges traffic with the PSN to which it is connected, its own community of users (connected directly or via an AMPE or I-S/A AMPE), and with external subscribers via a gateway.

The five nodal traffic flows of interest are:

- PSN_I - the average PSN input traffic (equal to the PSN output traffic)

- CSF_I - the average CSF input traffic

- CSF_O - the average CSF output traffic (greater than CSF_I due to the expansion associated with some traffic categories)

- E_I - the average I-S/A AMPE(E) input traffic

- E_O - the average I-S/A AMPE(E) output traffic (greater than E_I due to the expansion associated with some traffic categories).

Since six distinct categories of traffic contribute to each of these five flows, a total of thirty equations are required to describe traffic flows through the three types of network elements. These equations are functions of several parameters, relating to:

- the alternative architecture (e.g., number and type of service elements, distribution of functions/services among network elements, etc.)
- input traffic (rates specified in the baseline traffic model)
- subscriber type (i.e., AUTODIN I or II, local or remote)
- traffic category (e.g., traffic expansion factor, source-to-destination paths, functions/services required, etc.)
- network topology and connectivity (e.g., average number of PSNs between source and destination, average distance between a source and the nearest service element, etc.)

Applying the stated assumptions and ground rules, and using the basic traffic equations, the nodal element flows are computed for each traffic component. The aggregate traffic flow through the network elements of interest was then calculated by adding the various contributions.

Due to the number of computations involved, computer support was required for the calculation of traffic flows and to provide computer-generated plots of the key network output parameters, as a function of architecture and number of service elements. The most illustrative of these plots are presented and discussed in the following paragraphs.

Figure B-2 shows the average PSN throughput (i.e., input plus output) obtained by taking the PSN throughput for the entire network and dividing by the number of PSNs (eight). As in all the plots presented herein, a square is used for Architecture I data points, a triangle for Architecture II, and a diamond for Architecture III. For Architecture I, the X-axis represents the number of CSFs, while for Architectures II and III, the X-axis indicates the number of I-S/A AMPE(E)s. For Architecture III, the number of CSFs is varied from 1 to 8, resulting in a family of 8 curves. The Y-axis indicates the throughput traffic in busy hour kb/s. Most of the curves are plotted on identical scales to facilitate comparison.

The most conspicuous feature of Figure B-2 is the relatively small variation with architecture and number of service elements. Figure B-3 shows the same curves on an expanded scale. Note that all of the curves exhibit the same gross features: a sharp decrease in PSN traffic in going from 1 to 2 service elements, little decrease in going

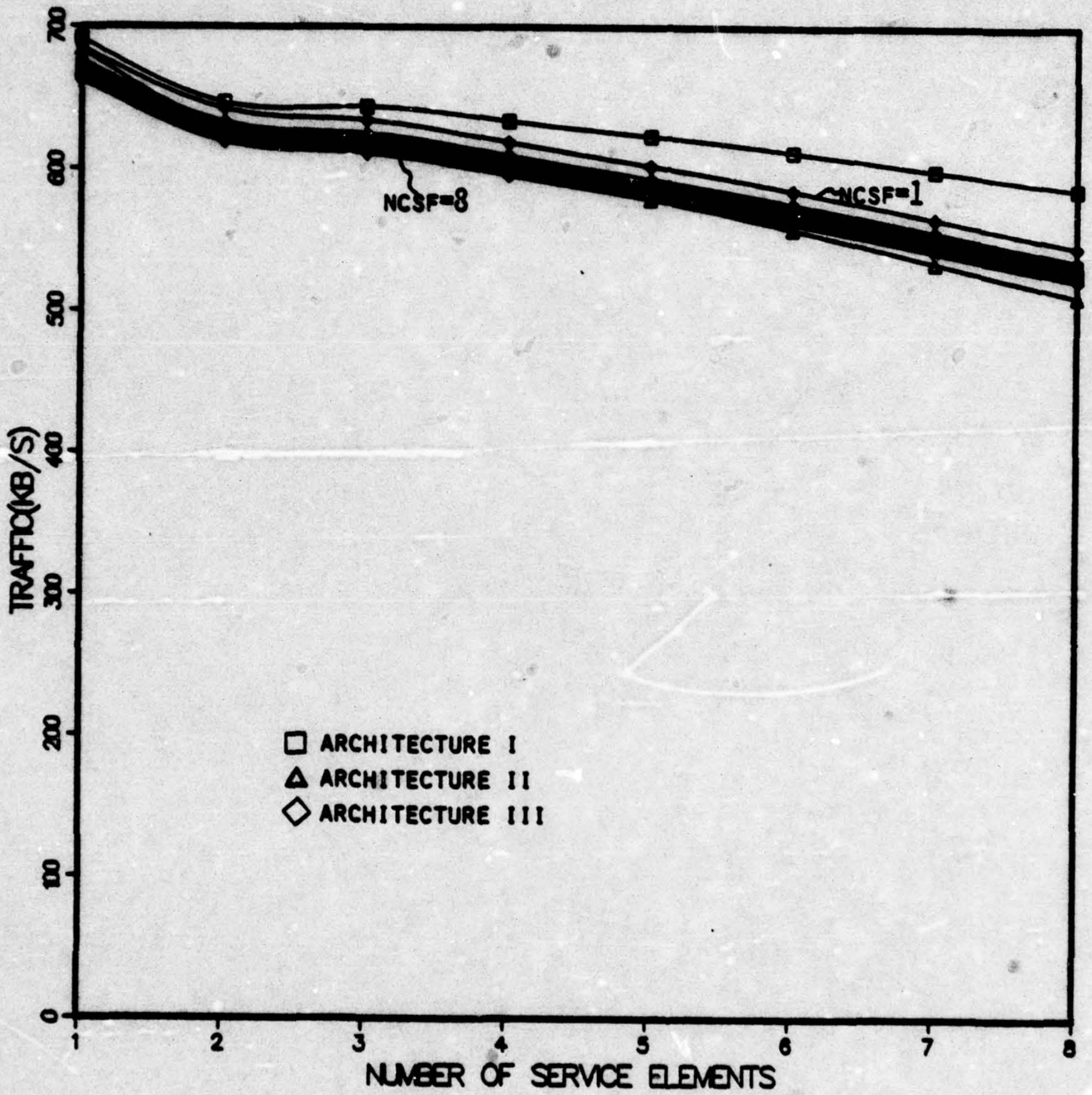


Figure B-2. Mean PSN Throughput

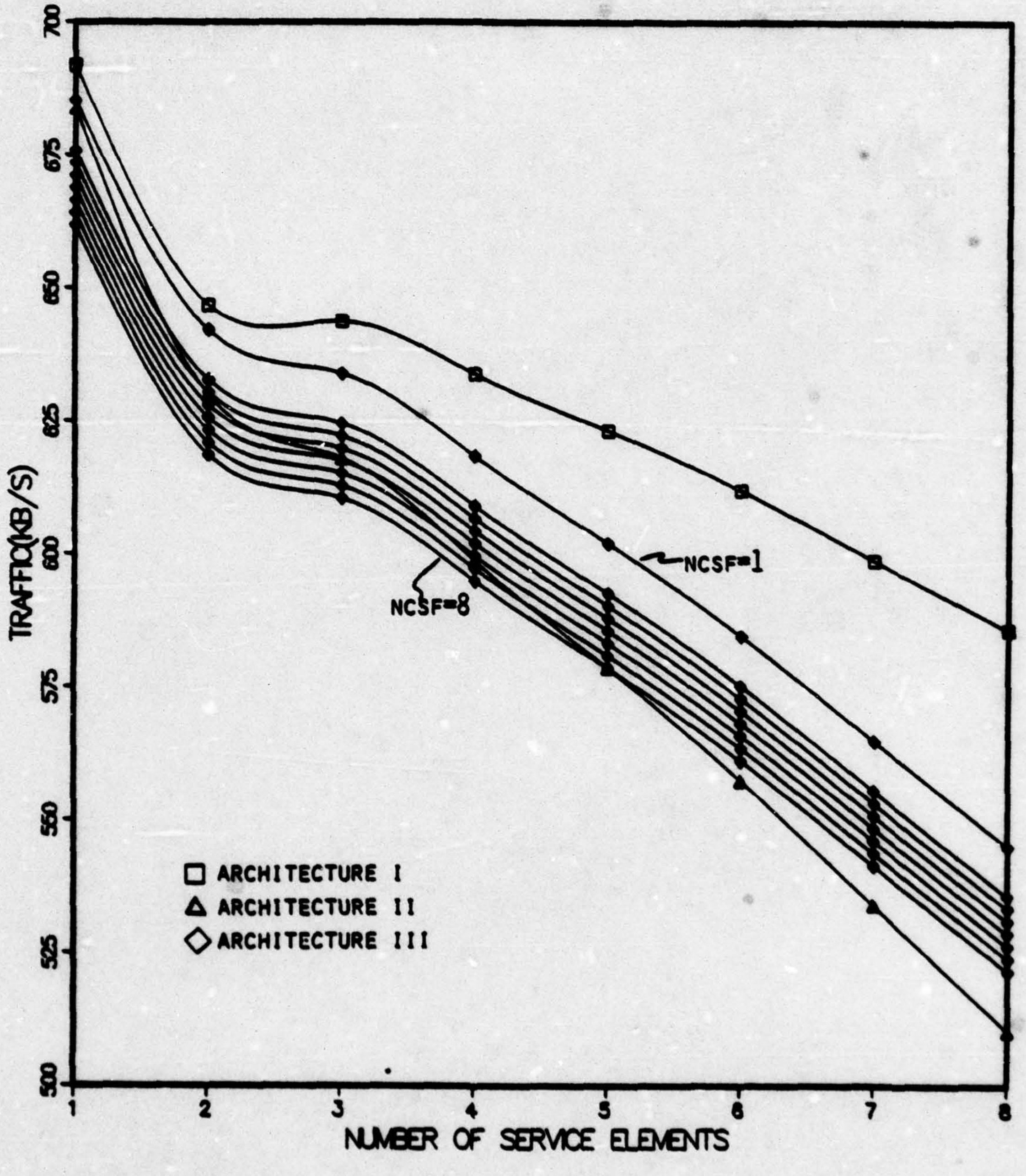


Figure B-3. Mean PSN Throughput (Expanded Scale)

from 2 to 3 service elements, and a roughly linear decrease thereafter. All of the Architecture III curves have the same slope, which is intermediate between the slopes of the Architecture I and II curves. As expected, Architectures II and III require less PSN capacity than Architecture I, primarily because of the ability of the I-S/A AMPE(E) to switch traffic to local users without using the backbone (this type of traffic comprises about 12 percent of the total network traffic).

Figure B-4 illustrates the average throughput per service element. Note that Architecture I requires significantly lower service element capacity than Architecture II for an equal number of service elements. The primary reason for this is the large amount of traffic that passes through I-S/A AMPE(E)s on the way from source to destination (including traffic which requires no service). Although Architecture III appears to be better than Architecture I in many cases, it should be remembered that the average service element throughput is greatly lowered by the presence of from 1 to 8 CSFs in addition to the number of I-S/A AMPE(E)s indicated by the X-axis.

For a somewhat fairer comparison, Figure B-5 shows the total (aggregate) service element throughput as a function of the number of CSFs or I-S/A AMPE(E)s. There is only one curve for Architecture III, because the total service element throughput is independent of the number of CSFs for this architecture (this is not true for Architecture I because in that architecture the mailbox function is performed in the CSF, and the number of intermediate messages required increases with the number of CSFs).

Figure B-6 presents a final comparison of total PSN throughput for the three architectures. In this figure, the X-axis presents the total number of service elements (number of CSFs plus number of I-S/A AMPE(E)s for Architecture III). The one curve shown for Architecture III is based on the combinations of CSFs and I-S/A AMPE(E)s that minimize the total PSN throughput. This optimized version of Architecture III exhibits throughputs slightly lower than Architecture II but somewhat higher than Architecture I. However, the particular combinations of I-S/A AMPE(E)s and CSFs that minimize the total PSN throughput may be sub-optimal in other respects. For example, in the case of 8 service elements, the lowest throughput for Architecture III occurs with 6 CSFs and only 2 I-S/A AMPE(E)s, a combination that could exhibit poor survivability and less than optimal response time.

The results of the nodal flow analysis were used in Appendix C to determine, for each architecture, the communications load on the network elements. This configuration was helpful in sizing the elements and estimating personnel requirements.

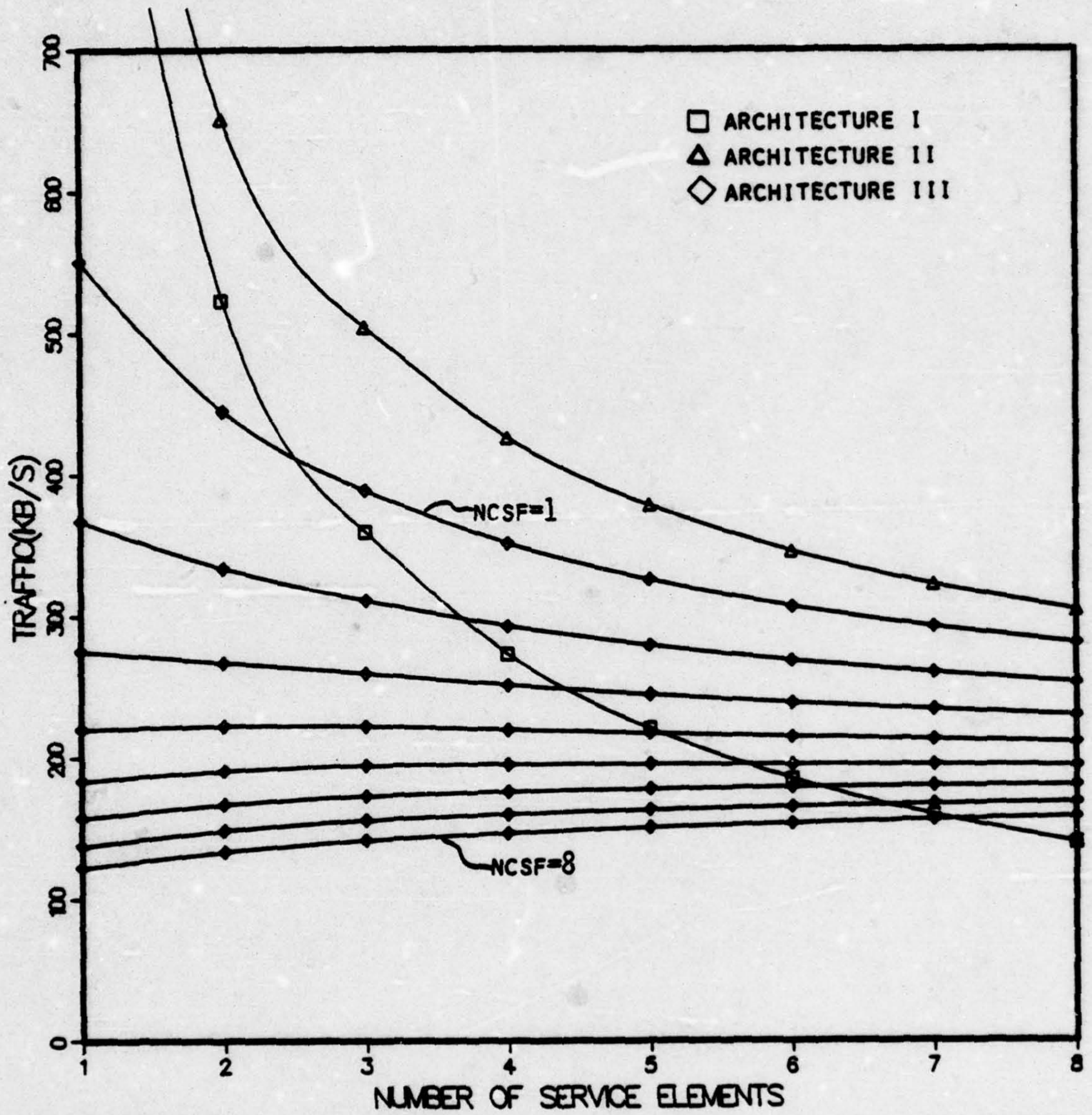


Figure B-4. Mean Service Element Throughput

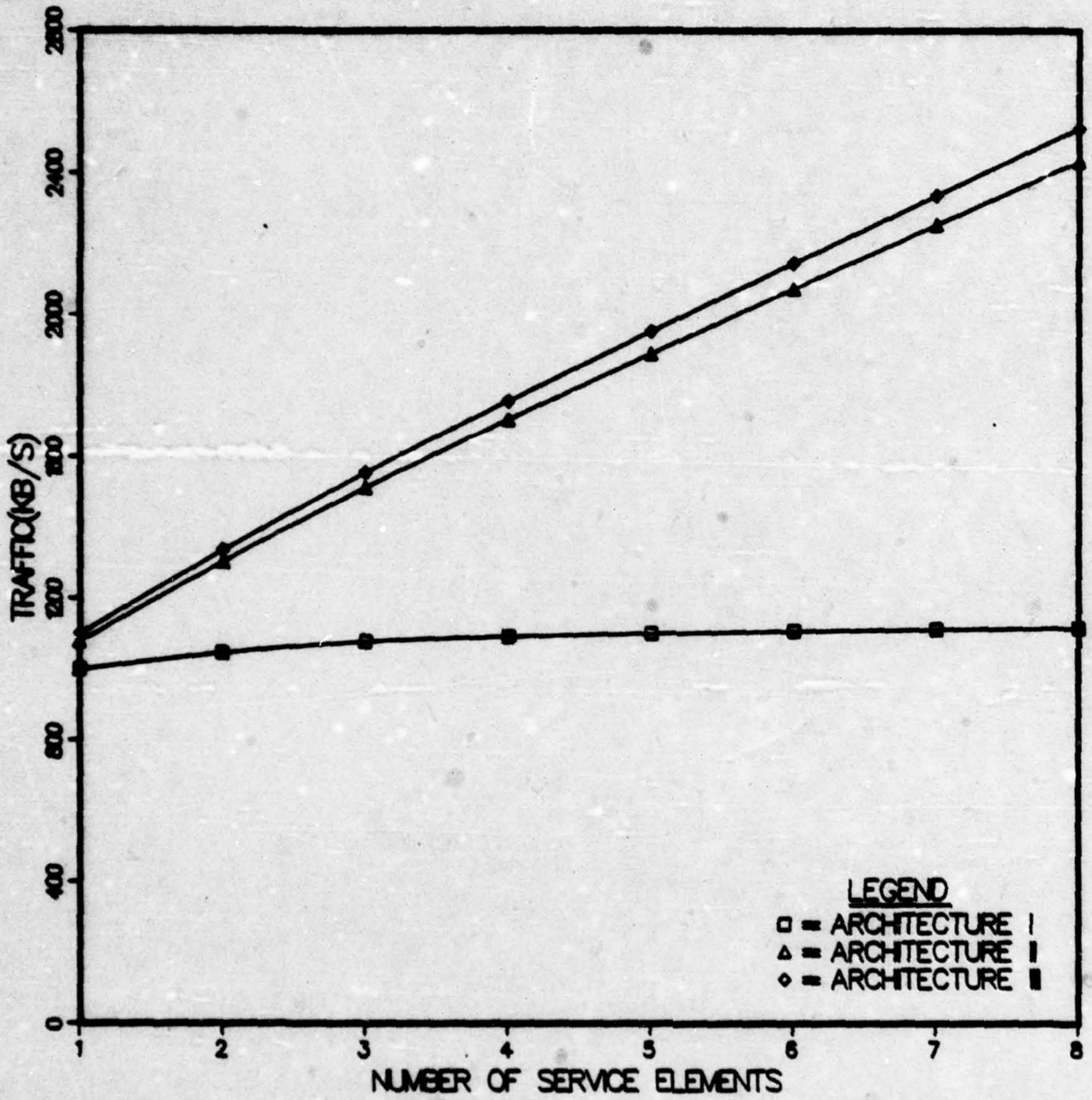


Figure B-5. Total Service Element Throughput

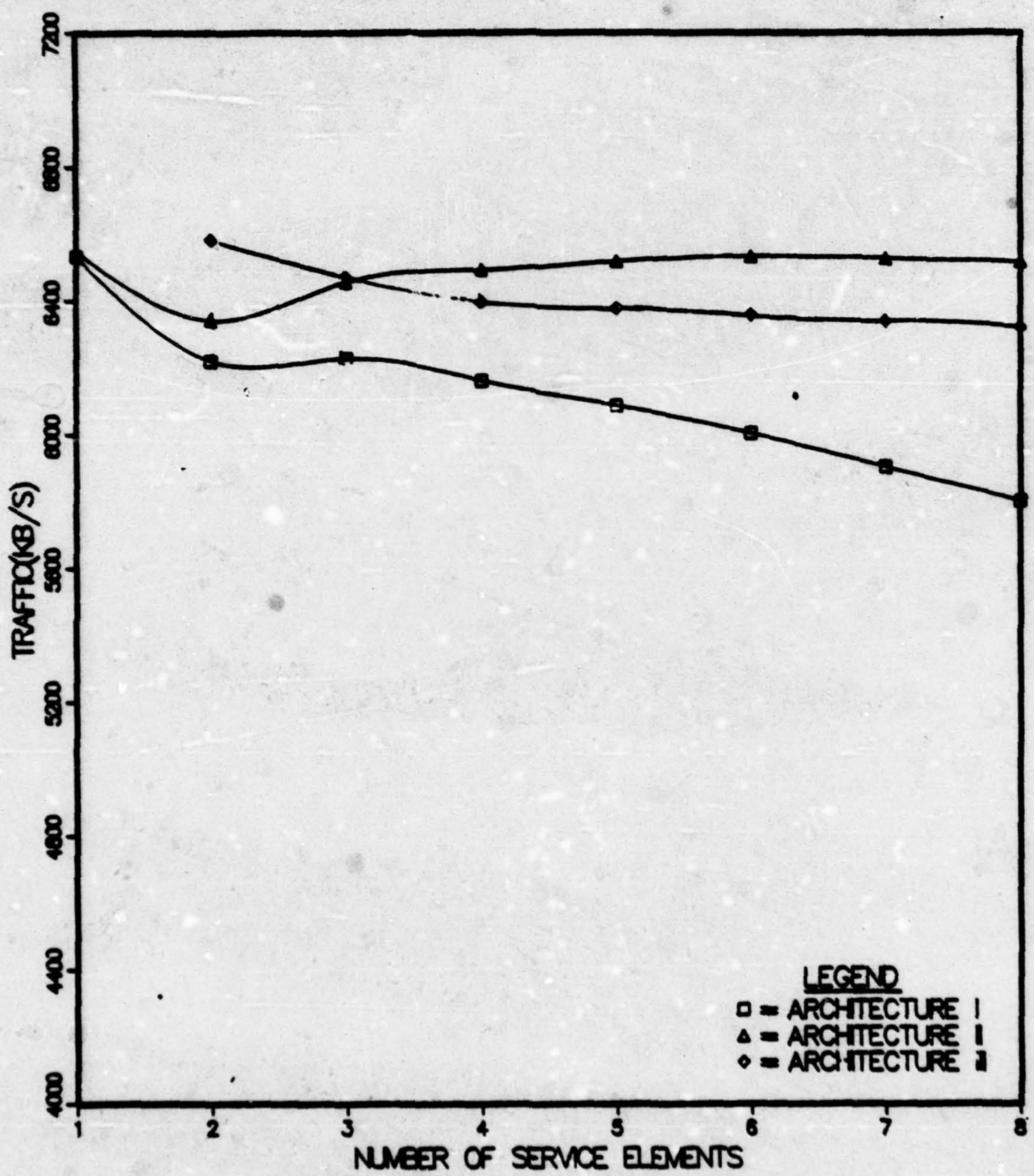


Figure B-6. Total PSN Throughput vs. Total Number of Service Elements (Architecture III Optimized)

b. Link Traffic. Once the nodal traffic flows are computed, as described in the preceding section, it is possible to calculate the average traffic flow on all major communication links between the nodal elements. This is done by applying conservation of traffic flow at each network element to obtain a set of equations.* (For the purpose of this analysis basic network element structures were defined which modeled the elements and the links between them.) The equations, based on assumptions similar to those used in calculating nodal flows, were solved to obtain the link flows of interest.

Again, because of the number of computations involved, computer support was used in calculating traffic flows. The link traffic analysis produced a series of circuit traffic values for each architecture as a function of the number of service elements. These results provide a major input into the transmission cost analysis (Appendix C).

c. Sensitivity Analysis. In order to ascertain the sensitivity of the results and conclusions of this study to variations in the input parameters, a number of computer runs were made in which the baseline parameter values were modified, one at a time. For each parameter varied, the resultant average change in the output parameters was calculated. The output parameters of interest are the average PSN throughput and the average service element throughput.

Two aspects of sensitivity are of interest to the study. First, does a large variation in the input parameter of interest have a large effect on the output parameters? Second, and more importantly, does the change have approximately the same effect with each architecture? The second question is more important to this study because architecture dependent variations could result in changes in the conclusions if input parameter values change significantly.

The results of the sensitivity analysis are summarized in Table B-III. The table shows that the results are rather insensitive to the number of PSNs and the PSN connectivity. Furthermore, the variations that do occur are fairly consistent from one architecture to another so that these parameters do not affect the conclusions.

Two parameters that describe the configuration of subscribers were examined: the fraction of traffic generated by I-S/A AMPE-terminated subscribers, and the fraction of I-S/A AMPEs directly connected to PSNs. Although the output parameters are not extremely sensitive to these input parameters, significant changes in the baseline values could conceivably affect some of the conclusions. For example, the service

*The algebraic sum of traffic flows entering and leaving a network element (taking into account traffic expansion at some elements) is equal to zero.

element throughput decreases when the first of these parameters increase for Architecture I; the reverse is true for the other two alternatives. Thus, if fewer subscribers are connected to I-S/A AMPEs, the advantage in lower service element throughput enjoyed by Architecture I will begin to shrink. At the same time, the PSN throughput advantage of Architecture II and III also shrinks.

A very similar situation exists with respect to the fraction of I-S/A AMPEs directly connected to PSNs. As this parameter increases, the difference in service element traffic among architectures decreases. However, the advantage in PSN throughput exhibited by Architectures II and III shrinks concomitantly. In fact, if the fraction is unity, Architectures I and II become identical, because there is no longer any difference between CSFs and I-S/A AMPE(E)s. As a result, we can conclude that connecting a smaller portion of the subscribers to I-S/A AMPE(E)s can be effected either by connecting more subscribers directly to PSNs or by connecting fewer I-S/A AMPEs to I-S/A AMPE(E)s. In either case, the differences between the three architectures may be diminished considerably.

Table B-III shows that the results are fairly insensitive to the fraction of local vs. remote traffic and the percentage of traffic requiring new functions. Again, the variations that do occur are quite consistent from one architecture to another.

Finally, the sensitivity analysis indicates that the results are fairly sensitive to the average number of addressees for traffic requiring AUTODIN I functions (i.e. Multiple-Address Traffic) but very insensitive to the expansion factors for Mailbox and Teleconferencing. This is to be expected since a much larger percentage of traffic requires AUTODIN I functions than requires the Mailbox and Teleconferencing functions. Nevertheless, the variations induced in the output parameters are remarkably consistent from architecture to architecture, so that the conclusions are unaffected by these two input parameters.

The sensitivity of comparative link traffic results is explored in the analysis of communications costs (Appendix C).

d. Effect of Dual Connected I-S/A AMPEs on Network Traffic. In all of the analysis presented thus far, it was assumed that each I-S/A AMPE was connected either directly to a PSN or to an I-S/A AMPE(E). As a consequence, traffic flowing to or from an I-S/A AMPE connected through an I-S/A AMPE(E) had to flow through the I-S/A AMPE(E) whether or not it required I-S/A AMPE(E) functions. This situation has an adverse impact on network survivability and on the cost of an I-S/A AMPE(E).

TABLE B-III. TRAFFIC FLOW SENSITIVITY ANALYSIS

BASELINE INPUT PARAMETER	NOMINAL PARAMETER VALUE	RANGE OF PARAMETER VALUES	IMPACT OF CHANGE
NUMBER OF PSNs	8	6 TO 12 (HOLDING THE TRAFFIC INPUT PER PSN CONSTANT)	• A PSN THROUGHPUT SWING OF ABOUT -6% TO +6% FOR ALL THREE ALTERNATIVES. • SERVICE ELEMENT THROUGHPUT SWING OF -1% TO +1% FOR ALTERNATIVE I; -2% TO +2% FOR ALTERNATIVE II; AND -6% TO +2% FOR III.
PSN CONNECTIVITY (NO. OF LINKS INCIDENT ON A PSN)	4	3 TO 6	• A +6% TO -6% SWING IN PSN THROUGHPUT. • AS EXPECTED, SERVICE ELEMENT THROUGHPUT WAS UNAFFECTED. • ALL THREE ALTERNATIVES DISPLAY THE SAME EFFECT.
FRACTION OF TRAFFIC GENERATED BY SUBSCRIBERS TERMINATED ON I-S/A AMPEs	0.67	90% BELOW TO 10% ABOVE NOMINAL VALUE	• PSN THROUGHPUT SWING FROM 8% ABOVE NOMINAL TO 1% BELOW NOMINAL. SIMILAR EFFECT ON ALL THREE ALTERNATIVES. • A +16% TO -3% CHANGE IN SERVICE ELEMENT THROUGHPUT FOR ARCHITECTURE I. • A -6% TO +2% CHANGE IN SERVICE ELEMENT THROUGHPUT FOR ARCHITECTURES II AND III.
PERCENTAGE OF I-S/A AMPEs DIRECTLY CONNECTED TO A PSN (DOES NOT APPLY TO ARCHITECTURE I)	0.30	0.30 TO 0.70	• A 4% INCREASE IN PSN THROUGHPUT. • THE I-S/A AMPE(E) THROUGHPUT IS REDUCED BY 20%. • ALTERNATIVES II AND III SHOW THE SAME BEHAVIOR.
FRACTION OF LOCAL TRAFFIC	0.25	40% BELOW TO 40% ABOVE NOMINAL VALUE	• MAXIMUM VARIATION OF +6% TO -6% IN PSN THROUGHPUT. • MAXIMUM VARIATION OF +3% TO -3% IN SERVICE ELEMENT THROUGHPUT. • SAME EFFECT ON ALTERNATIVES II AND III; SLIGHTLY LESS FOR ALTERNATIVE I.
FRACTION OF TRAFFIC REQUIRING NEW FUNCTIONS (I.E., TELECONFERENCING, MAILBOX, AND GATEWAY)	0.19	0.19 TO 0.35	• PSN THROUGHPUT INCREASE OF ABOUT 4% FOR ALL THREE ALTERNATIVES. • SERVICE ELEMENT THROUGHPUT INCREASE OF 20% FOR ARCHITECTURE I; AN INCREASE OF 10%-13% FOR THE OTHER TWO ALTERNATIVES.
AVERAGE NUMBER OF ADDRESSES FOR MULTIPLE-ADDRESS TRAFFIC	7	3 TO 11	• PSN THROUGHPUT SWING OF -27% TO +27% FOR ALL THREE ARCHITECTURES. • SERVICE ELEMENT THROUGHPUT SWING OF -26% TO +26% FOR ARCHITECTURE I; SLIGHTLY LESS FOR ALTERNATIVES II AND III.
EXPANSION FACTOR FOR MAILBOX AND TELECONFERENCING TRAFFIC	2.5	1.5 TO 3.5	• PSN THROUGHPUT SWING OF -6% TO +6% FOR ALL THREE ARCHITECTURES. • SERVICE ELEMENT THROUGHPUT SWING OF -6% TO +7% FOR ARCHITECTURE I; SLIGHTLY LESS FOR ALTERNATIVES II AND III.

One way to alleviate this problem is to dually connect all I-S/A AMPEs at nodes possessing an I-S/A AMPE(E) by connecting each I-S/A AMPE to its local PSN and to its local I-S/A AMPE(E). This procedure reduces the I-S/A AMPE(E) traffic flows to a level equal to the CSF traffic flows of Architecture I. At the same time, the PSN throughput decreases slightly because many I-S/A AMPEs that previously had to route traffic through a PSN to get to the local I-S/A AMPE(E), can now route traffic directly to the I-S/A AMPE(E).

The network flow calculations for Architecture II were revised based on the dual connection assumption described above. Traffic flows were recalculated with the number of I-S/A AMPE(E)s varied from one to eight. The salient results were as follows:

- The I-S/A AMPE(E) throughput was greatly reduced
  - I-S/A AMPE(E) input traffic decreased by 15 to 70 percent
  - I-S/A AMPE(E) output traffic decreased by 5 to 44 percent
- The PSN throughput decreased very slightly (a maximum of 7 percent
- Traffic flows in the access area were reduced by as much as 19 percent and significantly redistributed.

All three of these factors should have some impact on the cost and survivability of the IAS network.

4. CONCLUSIONS

It should be remembered that the purpose of the traffic flow analysis is to provide quantitative inputs to the cost analysis and technical factors evaluation process. Therefore, conclusions regarding the comparative desirability of the alternatives as a result of traffic flow considerations are not appropriate. However, in the process of performing this analysis, several significant findings were obtained:

- PSN traffic loading is relatively insensitive to architecture choice and will be determined principally by the number of service elements to be supported
- the dual connection of I-S/A AMPE nodes to a PSN and an I-S/A AMPE(E) results in a significant improvement of traffic distribution as well as element throughput requirements
- all three architecture alternatives are feasible.

As a result of this analysis, it is recommended that architecture Alternatives II and III make use of dual connection to a PSN and an I-S/A AMPE(E) as the preferred connection policy for the I-S/A AMPE.

APPENDIX C

MID-TERM IASA COST ANALYSIS AND RESULTS

APPENDIX C
COST ANALYSIS

1. INTRODUCTION

This appendix describes the major aspects and results of a comparative cost analysis performed in support of the mid-term IAS architecture definition effort. The analysis focused on two objectives: comparative evaluation of candidate mid-term architectures, and comparison between the preferred mid-term alternative and the baseline architecture projected to the mid-term.

A few preliminary observations are in order. First, the analysis of alternatives is comparative. Therefore, costs common to all of the alternatives have been excluded in order to simplify the analysis. Secondly the analysis seeks to select a least-cost alternative without resorting to an exhaustive life-cycle cost effort which would require detailed information on implementation strategy. Therefore, the analysis is limited to the level of detail necessary to the identification of trends and projections which provide an adequate basis for relative cost comparison and ranking among alternatives.

The basic approach to the cost analysis consists of the following steps:

- Identification and analysis of major cost elements. From a complete list of elements, only those found to be dependent upon network architecture have been retained. These are:
  - Transmission Cost
  - Nodal Element Acquisition Cost
  - Nodal Element Operation and Maintenance Cost.
- Identification of architecture dependent cost factors within each cost element. Again, costs which are common to all three architectures have been discarded.
- Development of cost estimating relationships or costing methods for each cost factor. In cases where a closed form expression is not applicable or is difficult to obtain, a costing method has been developed which produces the cost value for given parameter values.
- Evaluation of architecture dependent cost factors. The cost factors are evaluated using nominal parameter values.

- Sensitivity analysis. Parameters and assumptions are varied and the impact on cost is assessed. Those which drive the total cost are identified.

- Accumulation of cost factors and ranking of alternatives. The cost factors within each major cost element are evaluated and aggregated into a total element cost. The total cost, together with sensitivity and other considerations, is used to rank the alternatives.

- Overall cost ranking of alternatives. The results associated with each major cost element are combined into a final ranking. The relative weights of the cost elements are factored into this evaluation process.

Additional general assumptions and ground rules that support the cost analysis are presented below.

- The number of subscriber terminals and host computers in the system is independent of the architectural alternative. This cost component has been excluded from the comparative analysis.

- For simplicity, the cost impact of certain architectural issues was not factored into the analysis. Prime examples are security and system management and control. These issues were, however, addressed under various technical criteria (see Appendix D).

- Within each major cost element the analysis focused on those cost factors which contribute the most to total cost. Items subordinate to these primary factors will, in general, follow the primary factors and only increase the magnitude of any comparative cost difference.

- The cost calculations are expressed in current dollars. The uncertainty associated with the mid-term implementation strategy, as well as the requirement for comparative results, made the added complexity of price level and discount factors unjustifiable.

The cost analysis presented in this appendix assumes a typical 1988 network configuration for each alternative architecture for the purpose of computing nominal costs. Based on these mid-term configurations, a projected network element inventory was developed. This inventory took into account both geographic and survivability considerations in order to determine the probable minimum number of

each type of element required for each alternative. Typical CONUS and overseas configurations for the 1988 alternatives, as well as the expected 1983 baseline, are presented in Table C-I.

2. COMPARISON AMONG ALTERNATIVE MID-TERM ARCHITECTURES

a. Transmission Cost. Following the approach outlined above, comparative transmission costs for the three alternatives were computed. This involved sizing and costing various links in the network, using the backbone and access area topologies specified in the traffic model (described in a separate appendix).

The following assumptions and guidelines were used in analyzing transmission costs:

- Link traffic estimates were used in sizing communication lines. The analysis was limited to narrative/record (N/R) and bulk data transfer (BDT) traffic. Estimates of interactive and query/response requirements show these to represent a relatively minor contribution to total AUTODIN traffic (less than 5%). Narrative/record estimates were furnished by the traffic analysis computer model, which takes into account the various subscriber types, their distribution, connectivity and service requirements. Bulk data transfer estimates were computed in a similar manner. This traffic consists of terminal-to-computer and computer-to computer transfers, and requires no services from a CSF or I-S/A AMPE(E).

- Consistent with the comparative character of the analysis, those links carrying the same traffic in all three architectures were neglected. For the remaining links, however, the total traffic (architecture dependent and independent components) was used for sizing. This last category includes PSN-to-PSN and PSN-to-CSF links in the backbone, as well as I-S/A AMPE(E)-to-PSN and I-S/A AMPE-to-PSN links in the access area.

- Cost calculations were based on estimates of 1988 average busy hour traffic, assuming 1988 link configurations.

- Transmission facility lease costs were calculated based on available common carrier bulk tariffs for both voice-grade and wideband circuits. Rates (in current dollars) include mileage dependent and service (fixed) charges as follows:

TABLE C-I. TYPICAL CONFIGURATIONS

	BASELINE (1983)	PROJECTED BASELINE (1988)	ARCHITECTURE I (1988)	ARCHITECTURE II (1988)	ARCHITECTURE III (1988)
CONUS	8 PSN 4 ASC (COLOCATED WITH PSNs) 88 AMPE	8 PSN 4 ASC (COLOCATED WITH PSNs) 82 AMPE (REPLACE-MENT) 22 AMPE (ORIGINAL)	8 PSN 4 CSF 58 I-S/A AMPE 22 AMPE (ORIGINAL)	8 PSN 8 I-S/A AMPE(E) 50 I-S/A AMPE 22 AMPE (ORIGINAL)	8 PSN 4 CSF 8 I-S/A AMPE(E) 50 I-S/A AMPE 22 AMPE (ORIGINAL)
OVERSEAS	2 PSN 7 ASC (2 COLOCATED WITH PSNs) 26 AMPE	2 PSN* 7 ASC (2 COLOCATED WITH PSNs) 25 AMPE (REPLACE-MENT) 10 AMPE (ORIGINAL)	2 PSN* 2 CSF 20 I-S/A AMPE 10 AMPE (ORIGINAL)	2 PSN* 7 I-S/A AMPE(E) 13 I-S/A AMPE 10 AMPE (ORIGINAL)	2 PSN* 2 CSF 4 I-S/A AMPE(E) 16 I-S/A AMPE 10 AMPE (ORIGINAL)

*MINIMUM NUMBER OF PSN NODES ASSUMED FOR THIS ANALYSIS; ACTUAL NUMBER WILL BE BASED ON OVER-SEAS REQUIREMENTS TO BE DEFINED BY DCA.

- 56 Kbps trunks in the backbone - $6.72/mi/mo
  $920/mo

- 300-9600 baud lines in the access area - $0.56/mi/mo
  $86.60/mo.

(Source: Defense Commercial Communications Office.) All lines are full-duplex, with capacity determined by the largest of the two unidirectional flows.

- For simplicity, modem and multiplexer costs were assumed to be architecture independent, and were excluded from the calculations. In addition, no attempt was made to optimize circuit selection by mixing available offerings (the impact would be to lower all costs fairly evenly).

- A nominal line utilization factor of 50% was used in this study, to account for overhead, traffic growth, and delay performance requirements. The effect of varying this value is discussed later, as a sensitivity issue.

- All elements were assumed to be single-homed for simplicity. The impact of dual homing on transmission cost is addressed later.

- The transmission cost study is restricted to CONUS configurations. However, it is likely that overseas alternatives will either be very similar (i.e., architecture independent), or implemented according to the corresponding CONUS strategy, in which case the same comparative results (ranking) should hold.

Transmission cost is broken down into two major components: backbone cost (C_{BB}) and access area cost (C_{AA}). A more detailed classification of these costs is presented in Figure C-1. In order to exclude from the analysis costs common to all three alternatives, a device M (which could be thought of as "virtual multiplexer" or concentration point) and costs C_{PM} and C_{MI} were introduced. According to this scheme, C_{PM} incorporates the architecture dependent portion of PSN-to-I-S/A AMPE line cost, while C_{MI} accounts for the architecture independent portion. It should be noted that for a given alternative, one or more of the elements in Figure C-1 may equal zero.

Transmission costs used in the comparative analysis are the backbone cost (C_{BB}) and the architecture dependent portion of the access area costs ($C_{AA}(V)$). The cost expressions used in the computations are shown in Figure C-2.

$$C_T = C_{BB} + C_{AA}$$

$$C_{BB} = C_{PP} + C_{PC}$$

$$C_{AA} = \underbrace{C_{PS} + C_{IS} + C_{ES} + C_{PI} + C_{MI} + C_{EI}}_{C_{AA}(K)} + \underbrace{C_{PM} + C_{PE}}_{C_{AA}(V)}$$

C_T	-	Total Transmission Cost
C_{BB}	-	Backbone Cost
C_{AA}	-	Access Area Cost
$C_{AA}(K)$	-	Architecture Independent Segment of Access Area Cost
$C_{AA}(V)$	-	Architecture Dependent Segment of Access Area Cost
C_{PP}	-	Cost of PSN-PSN Links
C_{PC}	-	Cost of PSN-CSF Links
C_{PS}	-	Access Line Cost for PSN-Terminated Subscribers
C_{IS}	-	Access Line Cost for I-S/A AMPE - Terminated Subscribers
C_{ES}	-	Access Line Cost for I-S/A AMPE(E) - Terminated Subscribers
C_{PI}	-	Cost of PSN-I-S/A AMPE Links
C_{EI}	-	Cost of I-S/A AMPE(E)-I-S/A AMPE Links
C_{MI}	-	Cost of "Virtual Mux" - I-S/A AMPE Links
C_{PM}	-	Cost of PSN-"Virtual Mux" Links
C_{PE}	-	Cost of PSN-I-S/A AMPE(E) Links

Figure C-1. Transmission Cost Breakdown

- $C_{BB} = C_{PP} + C_{PC}$

$$C_{PP} = NL \cdot \left\lceil \frac{F_{PP}}{56 \cdot U} \right\rceil \cdot (920 + 6.72 \cdot D_{PP})$$

$$C_{PC} = NCSF \cdot H \cdot \left\lceil \frac{CSF_{OUT}}{56 \cdot H \cdot U} \right\rceil \cdot (920 + 6.72 \cdot D_{PC})$$

- $C_{AA}(V) = C_{PM} + C_{PE}$

$$C_{PM} = [NPSN - NI(E)] \cdot \left\lceil \frac{F_{PI} \cdot [NI + NI(E)] \cdot P_{IE}}{9.6 \cdot U \cdot NPSN} \right\rceil \cdot (86.6 + 0.56 \cdot D_{PI})$$

$$C_{PE} = NI(E) \cdot \left\lceil \frac{F_{EP}}{9.6 \cdot U} \right\rceil \cdot (86.6 + 0.56 \cdot D_{PE})$$

NOTE: $\lceil X \rceil$ means "smallest integer greater than or equal to X"

Figure C-2. Transmission Cost Estimating Relationships

Legend:

NL - number of PSN-PSN links in the network

NPSN - number of PSNs in the network

NCSF - number of CSFs in the network

NI - number of I-S/A AMPEs in the network

NI(E) - number of I-S/A AMPE(E)s in the network

U - line utilization factor

H - homing index (H = 1 for single homing, H = 2 for dual homing)

F_{PP} - average PSN-to-PSN link flow (in Kbps)

CSF_{OUT} - average CSF outgoing traffic flow (in Kbps)

F_{PI} - average PSN-to-I-S/A AMPE link flow (in Kbps)

F_{EP} - average I-S/A AMPE(E)-to-PSN link flow (in Kbps)

P_{IE} - fraction of I-S/A AMPEs which are connected to I-S/A AMPE(E)s (the same fraction is used for I-S/A AMPEs connected to "virtual multiplexers")

D_{PP} - average PSN-PSN mileage

D_{PC} - average PSN-CSF mileage

D_{PI} - average PSN-I-S/A AMPE mileage

D_{PE} - average PSN-I-S/A AMPE(E) mileage

Figure C-2. (Continued)

Monthly transmission costs for the three alternatives, as a function of the number of service elements (CSFs and/or I-S/A AMPE(E)s), are presented in Tables C-II and C-III. The two cases represent different fractions of I-S/A AMPEs directly connected to PSNs (instead of PSN connection through an intermediate element, such as an I-S/A AMPE(E)).

From the results obtained, it is apparent that there is no significant variation in transmission cost among the three alternatives. As would be expected, Architecture I shows a slightly greater cost than the other two alternatives. This stems from the fact that all traffic requiring services must access a backbone-homed CSF. On the other hand, Alternatives II and III offer some or all of these services closer to the subscriber, in access area elements. In any event, the variation in total cost is no greater than about 6%. If costs common to all three architectures were included, this variation would be further reduced.

In Tables C-II and C-III the number of service elements and the connection strategy for I-S/A AMPEs were chosen as architectural variables, while holding other parameters constant. In order to assess the impact of several of the assumptions discussed earlier, the sensitivity of the results to changes in these parameters was investigated. The parameters were varied over a reasonable range of values so as to identify trends in the behavior of the cost results. The findings are summarized in Table C-IV. As indicated in the table, variations in most parameters tend to affect all three architectures fairly equally, thus producing no significant effect on the comparative evaluation.

It should be noted that the cost comparison applies to 1988 configurations. However, given the similar topologies of the three architectures, as well as the likelihood of comparable 1983-1988 transition plans, the results can be expected to hold throughout the mid-term.

In view of these considerations, transmission cost does not represent a driving factor in the selection of a preferred architecture. The cost variations obtained are of the same order of magnitude as the error associated with many of the underlying assumptions. Thus, no alternative can be singled out as best and the three architectures have been ranked equally.

b. Nodal Element Acquisition Cost. The comparative evaluation of potential acquisition costs for the alternative mid-term architectures relied on the following guidelines and assumptions:

TABLE C-II. TRANSMISSION COST RESULTS

SINGLE HOMING/50% LINE UTILIZATION/30% OF I-S/A AMPEs DIRECTLY CONNECTED TO PSN

N	COST [$ K/MO.]												
	ARCHITECTURE I [N = # CSF]			ARCHITECTURE II [N = # I - S/A AMPE(E)]			ARCHITECTURE III [N = # I - S/A AMPE(E)]						
	0 I -S/A AMPE (E)			0 CSF				1 CSF		4 CSF		8 CSF	
	C_{BB}	$C_{AA}(V)$	C_T	C_{BB}	$C_{AA}(V)$	C_T	$C_{AA}(V)$	C_{BB}	C_T	C_{BB}	C_T	C_{BB}	C_T
1	492.8	31.8	524.6	458.9	58.4	517.3	55.0	463.9	518.9	463.9	518.9	468.9	523.9
2	494.1	31.8	525.9	458.9	56.7	515.6	53.6	463.9	517.5	463.9	517.5	468.9	522.5
3	496.6	31.8	528.4	458.9	55.1	514.0	52.1	463.9	516.0	463.9	516.0	468.9	521.0
4	499.1	31.8	530.9	458.9	52.4	511.3	49.3	463.9	513.2	463.9	513.2	468.9	518.2
5	496.6	31.8	528.4	458.9	49.6	508.5	47.6	463.9	511.5	463.9	511.5	468.9	516.5
6	496.6	31.8	528.4	458.9	47.2	506.1	44.8	463.9	508.7	463.9	508.7	468.9	513.7
7	502.9	31.8	534.7	458.9	44.2	503.1	42.8	463.9	506.7	463.9	506.7	468.9	511.7
8	501.1	31.8	532.9	458.9	42.9	501.8	39.7	463.9	503.6	463.9	503.6	468.9	508.6

C_{BB} = TOTAL BACKBONE TRANSMISSION COST FOR N/R AND BDT TRAFFIC (INCLUDES PSN-CSF LINKS IN ARCHITECTURES I AND III)

$C_{AA}(V)$ = ARCHITECTURE DEPENDENT PORTION OF ACCESS AREA TRANSMISSION COST FOR N/R AND BDT TRAFFIC

C_T = $C_{BB} + C_{AA}(V)$

TABLE C-III. TRANSMISSION COST RESULTS

SINGLE HOMING/50% LINE UTILIZATION/70% OF I-S/A AMPEs DIRECTLY CONNECTED TO PSN

N	COST ($ K/MO.)												
	ARCHITECTURE I [N = # CSF] O I - S/A AMPE(E)			ARCHITECTURE II [N = # I - S/A AMPE(E)] O CSF			ARCHITECTURE III [N = # I - S/A AMPE(E)]						
								1 CSF		4 CSF		8 CSF	
	C_{BB}	$C_{AA}(V)$	C_T	C_{BB}	$C_{AA}(V)$	C_T	$C_{AA}(V)$	C_{BB}	C_T	C_{BB}	C_T	C_{BB}	C_T
1	492.8	14.3	507.1	458.9	43.5	502.4	39.9	463.9	503.8	463.9	503.8	468.9	508.8
2	494.1	14.3	508.4	458.9	43.3	502.2	39.7	463.9	503.6	463.9	503.6	468.9	508.6
3	496.6	14.3	510.9	458.9	42.9	501.8	39.3	463.9	503.2	463.9	503.2	468.9	508.2
4	499.1	14.3	513.4	458.9	42.1	501.0	38.9	463.9	502.8	463.9	502.8	468.9	507.8
5	496.6	14.3	510.9	458.9	41.1	500.0	38.2	463.9	502.1	463.9	502.1	468.9	507.1
6	496.6	14.3	510.9	458.9	40.5	499.4	37.0	463.9	500.9	463.9	500.9	468.9	505.9
7	502.9	14.3	517.2	458.9	39.3	498.2	36.6	463.9	500.5	463.9	500.5	468.9	505.5
8	501.1	14.3	515.4	458.9	38.1	497.0	35.0	463.9	498.9	463.9	498.9	468.9	503.9

C_{BB} = TOTAL BACKBONE TRANSMISSION COST FOR N/R AND BDT TRAFFIC (INCLUDES PSN-CSF LINKS IN ARCHITECTURES I AND III)

$C_{AA}(V)$ = ARCHITECTURE DEPENDENT PORTION OF ACCESS AREA TRANSMISSION COST FOR N/R AND BDT TRAFFIC

C_T = $C_{BB} + C_{AA}(V)$

TABLE C-IV. TRANSMISSION COST SENSITIVITY ANALYSIS

ARCHITECTURAL PARAMETER	NOMINAL VALUE	IMPACT OF CHANGE
NUMBER OF PSNs	8 (CONUS)	• C_{BB} IS A FUNCTION OF THE NUMBER OF PSNs IN ALL THREE ALTERNATIVES • NO IMPACT ON COST RANKING
LINE UTILIZATION FACTOR (U)	50%	• NEAR LINEAR COST SCALING • NO IMPACT ON COST RANKING
FRACTION OF TRAFFIC DESTINED FOR LOCAL SUBSCRIBERS (I.E., REMAINING IN THE ACCESS AREA)	25%	• CHANGE IN RATIO OF BACKBONE TO ACCESS AREA TRAFFIC • NO MAJOR EFFECT ON RELATIVE COST RANKING
FRACTION OF I - S/A AMPEs CONNECTED DIRECTLY TO PSNs	30% (TABLE C-II) 70% (TABLE C-III)	AS THIS FRACTION INCREASES THE DISTINCTION BETWEEN ALTERNATIVES I AND II BECOMES BLURRED
LOCATION OF CSFs (SINGLE HOMING ASSUMED)	AVERAGE PSN - TO - CSF DISTANCE OF 50 MILES	• PSN - CSF TRANSMISSION COST IS PROPORTIONAL TO DISTANCE • ARCHITECTURE I DISPLAYS GREATEST IMPACT
LOCATION OF I - S/A AMPE(E)s (SINGLE HOMING ASSUMED)	AVERAGE PSN - TO - I - S/A AMPE(E) DISTANCE OF 200 MILES	COLOCATION WITH PSN SLIGHTLY REDUCES ACCESS AREA COSTS FOR ALTERNATIVES II AND III (REDUCTION IS SOMEWHAT GREATER FOR ARCHITECTURE II)
NUMBER OF SUBSCRIBERS AND/OR TRAFFIC VOLUME	AS SPECIFIED IN CHAPTER II OF THIS REPORT	• LINEAR COST SCALING • NO IMPACT ON RELATIVE COST RANKING
HOMING	ALL ELEMENTS SINGLE HOMED	• DUAL HOMING OF CSFs AND I-S/A AMPEs CAN CAUSE A 5 - 15% INCREASE IN TRANSMISSION COSTS • INCREASE IS SOMEWHAT GREATER FOR ARCHITECTURE I

- The estimation of acquisition costs focused on nodal element hardware costs, as well as basic operating system software costs. A software-first development approach was assumed for applications software (which supports AUTODIN functions and services), using transportable software modules designed to run on all of the alternative hardware configurations. Since all three architectures must provide the same functions and services, applications software development costs were regarded as architecture independent and excluded from the analysis.

- Security functions (e.g., access control, key distribution) and multilevel security are to be provided through separate subsystems. As mentioned earlier, these issues were addressed under technical rather than cost criteria (see Appendix D). In any event, it is expected that the implementation cost will be fairly uniform for the three alternatives.

- The cost of militarization of nodal element hardware (I-S/A AMPE, I-S/A AMPE(E) and CSF) has been excluded from the analysis. The requirements for militarization of nodal element hardware are independent of architecture.

- Although some nodal elements may be leased, the cost estimating approach made use of one-time acquisition costs for convenience. In situations requiring an annual cost figure, the one-time cost was distributed uniformly over a ten year economic lifetime.

- In the specification of nodal hardware configurations maximum commonality and modularity were assumed. Furthermore, the nodal elements were based on a multiprocessor architecture.

- Cost estimates for network elements were based on commercial hardware suitable for a fixed plant environment, and do not include the cost of spare parts, documentation or other support costs.

- Acquisition cost figures are expressed in 1978 dollars.

In accordance with the preceding ground rules, acquisition costs of all major network elements were estimated using the approach described below.

- Representative hardware configurations were defined for the nodal elements of each alternative architecture (PSNs were assumed architecture independent, and excluded from the analysis). These configurations are required to support:

  - Communications Processing
  - Service Processing
  - Control Processing.

  Each element was defined in terms of a standard set of hardware components (e.g., processor, memory, peripherals) selected from typical state-of-the-art communications processing systems.

- The network elements were sized, using the set of standard components, based on the following inputs:

  - The functional capabilities required to support services allocated to the nodal elements
  - The projected nodal throughput requirements provided by the automated traffic model
  - Typical subscriber circuit and network trunk inventories (classified according to transmission speed and link protocol), derived from available AUTODIN projections.

  These inputs were used to determine the requirements for processing power, memory and peripherals, as well as the operating system to manage them.

- Network element costs were then computed, based on hardware component cost estimates collected through vendor surveys and available literature.

- Finally, the total nodal element acquisition cost was compiled for each alternative mid-term architecture, using the typical network configuration of Table C-I.

The Tymshare Engine, a commercial processor, was selected as the basic building block in defining nodal element configurations. This unit, used as a nodal processor in a value-added network (Tymnet), was chosen for several reasons:

- The Engine was specifically designed for communications processing.

- It is suitable for a multiprocessor nodal architecture, and is fairly modular in structure.

- It evolved from the Interdata 7/32, a well-known mini-computer. Furthermore:

  - It is similar to the ATP-5/6, a version of the AMPE which is also based on the 7/32

  - It is software compatible with the 7/32, and is supported by the same peripherals

  - It is a more powerful enhanced version of the 7/32.

- The Engine is representative of state-of-the-art technology.

The Engine should be viewed as a "strawman" hardware implementation useful in a comparative analysis, rather than a nodal architecture recommendation.

The nodal element hardware sizing procedure is illustrated in Figure C-3, for the case of an I-S/A AMPE (common to all three architectures). The configuration includes two Engine processors, one for communication processing and one for service processing (with control functions present in both), as well as the necessary peripherals, storage devices and I/O ports.

To avoid redundant effort, the specification of hardware configurations was performed on network elements in order of increasing capability. In this way, the structure of one element could build on the hardware configuration of a less powerful element (which supports a subset of the functions and services of the first one) by adding extra components and capabilities. The results of the nodal element acquisition cost analysis are shown in Figure C-4. The diagram also depicts the order in which these elements were configured, starting from a set of standard components. The cost of an I-S/A AMPE was calculated in spite of its architecture independence, since it represents an intermediate step in the definition of an I-S/A AMPE(E). The "large" and "small" versions of the I-S/A AMPE(E)s result from different assumed I-S/A AMPE(E) populations. The smaller, more pervasive type is assumed in the typical configurations presented in Table C-I and used throughout this study.

Based on typical 1988 network configurations and derived element acquisition costs, the overall acquisition cost for each alternative architecture was computed. The results are summarized in Table C-V. Elements irrelevant to a comparative analysis have been excluded. It is evident from the results that total nodal element acquisition cost does not vary greatly among the alternatives. In addition, when the expected economic life of the elements is considered (around 10 years), the potential difference in annual lease cost becomes less significant.

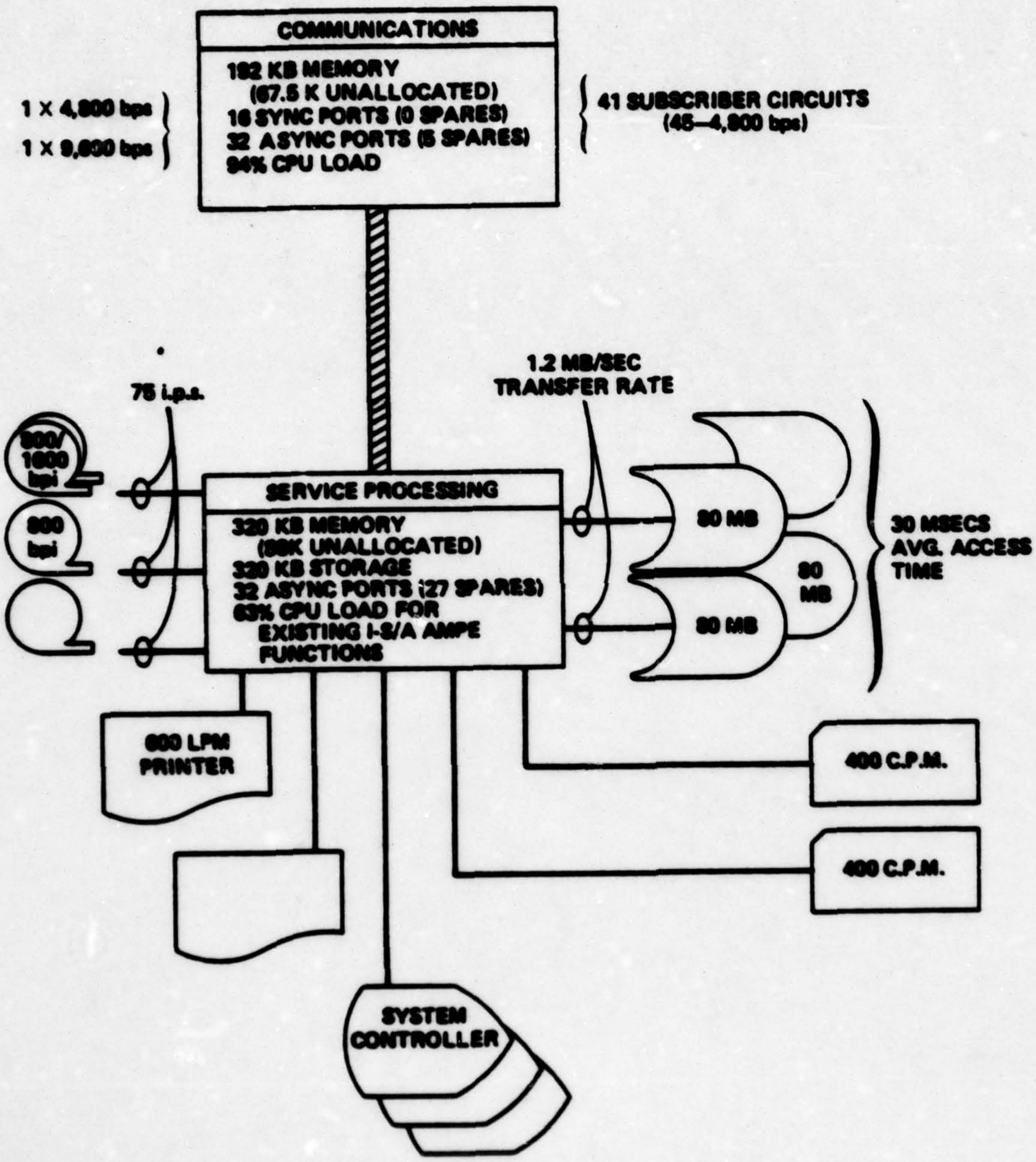


Figure C-3. Representative Nodal Element Sizing Approach (I-S/A AMPE)

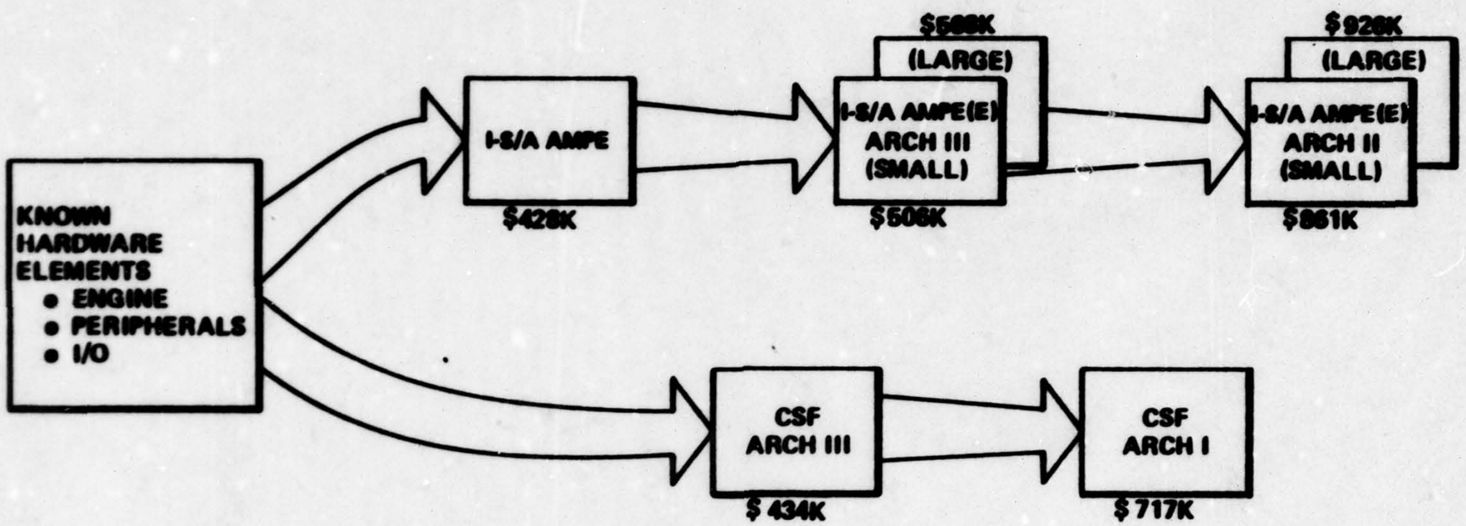


Figure C-4. Nodal Element Acquisition Cost Results

TABLE C-V. PROJECTED NETWORK ELEMENT ACQUISITION COST

ARCHITECTURE ALTERNATIVE	NODAL ELEMENT INVENTORY	ESTIMATED COST PER ELEMENT	ESTIMATED SYSTEM ACQUISITION COST (1978 $)
I	6 CSF 78 I-S/A AMPE	CSF – $717K I-S/A AMPE – $428K	$37.7M
II	63 I-S/A AMPE 15 I-S/A AMPE(E)	I-S/A AMPE – $428K I-S/A AMPE(E) – $861K	$39.9M
III	6 CSF 66 I-S/A AMPE 12 I-S/A AMPE(E)	CSF – $434K I-S/A AMPE – $428K I-S/A AMPE(E) – $506K	$36.9M

NOTES

1. EACH ELEMENT HAS BEEN DEFINED IN TERMS OF HARDWARE COMPONENTS SELECTED FROM TYPICAL STATE-OF-THE-ART COMMUNICATIONS PROCESSING SYSTEMS.

2. COST ESTIMATES REPRESENT PROJECTED ACQUISITION COSTS FOR NETWORK ELEMENTS BASED ON COMMERCIAL HARDWARE SUITABLE TO A FIXED PLANT ENVIRONMENT, AND DO NOT INCLUDE THE COST OF SPARE PARTS, DOCUMENTATION, OR OTHER SUPPORT COSTS.

3. COST ESTIMATES DO NOT INCLUDE AMORTIZATION OF HARDWARE OR SOFTWARE DEVELOPMENT COSTS.

4. ELEMENT INVENTORIES ARE BASED ON TYPICAL 1988 NETWORK CONFIGURATIONS.

Several observations should be made in the area of sensitivity. First, the simplifying assumption of uniform software development costs does not reflect the additional complexity and cost of developing and implementing software for more than one service element. Taking this into account would penalize Alternative III while making Alternative II more attractive. The likely effect would be to reverse the acquisition cost ranking presented in Table C-V, showing a slight preference for Architecture II. The variation in cost, however, should still be relatively insignificant.

Finally, the assumption that would appear to have the greatest impact on the acquisition cost ranking is the number of network elements (i.e., the assumed 1988 configurations). However, because of performance and survivability constraints, no appreciable variation from the nominal values is anticipated. Furthermore, the cost advantage of a decrease in the population of a service element is partially offset by an increase in unit cost for the remaining elements, arising from additional throughput and service processing requirements.

c. Operation and Maintenance Cost. Of the major components of operation and maintenance (O & M) cost - personnel, spares and backup equipment, facilities support (O & M of installations), and utilities - personnel costs represent the largest contribution to total cost. In view of this, the analysis of operation and maintenance cost focuses on personnel requirements, and addresses the remaining factors in terms of the sensitivity of the results.

The basic approach to calculating personnel costs for the candidate architectures is described below:

- Manning requirements for each nodal element type (by personnel category) were estimated based on available history of existing ASC and AMPE operations

- Average annual costs, by personnel category, were computed based on available DCA cost information

- The total personnel requirements and resultant annual costs were compiled for each alternative, using the typical 1988 nodal element inventories presented in Table C-I.

Projected manning requirements and annual pay rates (by personnel category) used throughout the operation and maintenance cost analysis are shown in Table C-VI. The table includes present ASC and AMPE levels for reference, as well as estimated levels for nodal elements used in the alternative mid-term architectures and the projected baseline.

TABLE C-VI. 1988 PERSONNEL REQUIREMENTS ESTIMATES

PERSONNEL CATEGORY		ABC 1978 LEVELS	ABC 1988 LEVELS	AMPE 1978 LEVELS	AMPE 1988 LEVELS (ORIGINAL)	AMPE 1988 LEVELS (REPLACE-MENT)	FORMER AMPE (AFTER REVERTING TO MESSAGE CENTER STATUS)	I-S/A AMPE	I-S/A AMPE (E) (ARCH. III)	I-S/A AMPE (L) (ARCH. III)	CSF (ARCH. III)	CSF (ARCH. II)	PSN
OFFICER IN CHARGE @ $32,500		1	1	1	1	1	–	1	1	1	1	1	1
MANAGEMENT & ADMIN-ISTRATION @ $21,200		10	10	5	5	5	1	6	7	7	5	6	4
COMPUTER OPERATORS @ $10,000	OPERATIONS @ $10,200	29	20	40	40	40	19	40	42	44	20	28	20
TECH CONTROL @ $10,200		10	10										
SYSTEMS & SOFTWARE (ON-SITE PROGRAMMERS . . .) @ $27,600		3	3	2	2	2	–	2	2	2	2	2	2
COMSEC MAINTENANCE (CRYPTO) @ $10,600		25	10	19	14	14	4	14	14	14	3	3	10
(OTHER) HARDWARE MAINTENANCE @ $10,600		35	20	30	30	22	4	22	22	24	12	16	20
FACILITIES OPERATIONS & MAINTENANCE @ $17,000		6	6	3	3	3	2	3	6	6	3	6	6
TOTAL PERSONNEL		127	113	100	95	87	30	88	94	98	46	62	63
TOTAL COST ($K/YR) (1977 DOLLARS)		2,464	2,194	1,927	1,834	1,686	571	1,706	1,820	1,886	910	1,213	1,222

TABLE C-VI. (Continued)

Notes

1. "ASC 1988 Levels" represent reduced O & M personnel requirements that will result from introduction of new technology replacement subsystem during 1978-1988 period (e.g., second generation crypto equipments).

2. "AMPE 1988 Levels (Original)" represents O & M personnel requirements for AMPEs which are deployed during the near-term and remain in operation throughout the mid-term. The only personnel reduction relative to present levels arises in the area of crypto maintenance, as a result of the introduction of second generation equipment.

3. "AMPE 1988 Levels (Replacement)" represent O & M personnel requirements for AMPEs which are deployed during the mid-term to replace certain near-term AMPEs. These replacement AMPEs show a reduction in hardware maintenance requirements as a result of a certain degree of standardization and technological innovation in many of the subsystems.

4. Manning levels include only those personnel whose primary responsibility centers around the proper functioning of the network elements.

5. The Hardware Maintenance category has been included for comparative purposes (in many instances this service is provided by a contractor).

6. The Facilities Operations & Maintenance category includes power production, air conditioning maintenance, etc.

7. The personnel requirements represent site totals, assuming four shifts.

8. Manning levels are assumed to be averaged over the total population of an element (both CONUS and Overseas).

9. Yearly costs are weighted averages of the ASC personnel breakdown under each major category. The appropriate rates are taken from Reference b and include base pay plus costs for retirement, training, recruiting and other support costs. Costs are in 1977 dollars.

The estimates for ASC and AMPE personnel were obtained from available data on existing operations. In particular, personnel requirements for the ASCs are based on 1977 authorized levels for the Croughton and Pirmasens installations. They include some indirect personnel (i.e., those whose primary duty is outside the Sensitive Compartmented Information (SCI) Accredited Area), primarily in the areas of facilities O & M and hardware maintenance. Some categories have been aggregated for simplicity (e.g., Hardware Maintenance includes Computer, DSTE, Teleypewriter and Modem Maintenance). The standard personnel categories used throughout the manning analysis are indicated in Table C-VI. Estimates for AMPE personnel requirements were based on proposed manning levels for the Stuttgart AMME and additional information on operation and maintenance personnel found in Reference a as a starting point. In order to ensure a meaningful comparison among network elements, the personnel categories from both sources were mapped into the standard categories developed for the ASC. An example of this mapping for the Stuttgart AMME is shown in Table C-VII. (Those categories not included in the AMME reference were estimated by extrapolation from Reference a and/or available estimates for the same categories.) Finally, the requirements for each category were adjusted to account for variations in AMPE types and sizes (the values in Table C-VI represent overall averages.)

The manning estimates for proposed new IAS elements were obtained using the available ASC and AMPE information as a baseline. These figures were then projected and adjusted for each element in question, with consideration given to:

- Element throughput requirements
- Anticipated processing capabilities
- Communication line and trunk terminating requirements
- Advances in technology

The following additional assumptions and guidelines were used in preparing Table C-VI:

- The Hardware Maintenance category has been included for comparative purposes, to illustrate the potential savings offered by the new IAS elements (maintenance is provided by contractors in all CONUS and many overseas elements).

- The manning levels shown in the table include more than just the operations personnel (as found in many references), but are restricted to personnel whose primary responsibility centers around the proper functioning of the network element.

- The personnel requirements represent site totals, assuming four shifts.

TABLE C-VII. SAMPLE MAPPING INTO STANDARD PERSONNEL CATEGORIES

STANDARD CATEGORY	STUTTGART AMME CATEGORY	STUTTGART AMME PROPOSED PERSONNEL COUNT
OFFICER IN CHARGE	NOT INCLUDED	–
MANAGEMENT AND ADMINISTRATION	MANAGEMENT AND ADMINISTRATION	5
OPERATIONS	• COMM. CENTER OPERATIONS • OPERATIONS • ELEC. REPAIR SEC. • PATCH & TEST	13 22 2 5 TOTAL = 42
SYSTEMS AND SOFTWARE	SYSTEMS AND SOFTWARE	2
COMSEC MAINTENANCE	COMSEC MAINTENANCE	19
(OTHER) HARDWARE MAINTENANCE	NOT INCLUDED (CONTRACTOR SERVICE)	–
FACILITIES O&M	NOT INCLUDED	–
		TOTAL = 68

NOTES:

1. MANNING LEVELS REPRESENT SITE TOTALS, ASSUMING FOUR SHIFTS.

2. PERSONNEL REQUIREMENTS ARE PROPOSED 1988 LEVELS.

- Manning levels are assumed to be averaged over the total population of an element (both CONUS and Overseas).

- Yearly costs were weighted averages of the ASC personnel breakdown under each major category. The appropriate rates are taken from Reference b (Tables 23-2 and 24-2) and include base pay plus costs for retirement, training, recruiting and other support costs (according to DCAI 600-60-1). Cost figures are in 1977 dollars.

From the information derived on manning levels and costs, system personnel requirements and total annual costs were computed for the alternative architectures. The results are summarized in Table C-VIII. As indicated in this table, Alternative II represents a savings of approximately 200 personnel which would result in an estimated annual O & M cost reduction of approximately $4 million. This savings results primarily from the fact that Alternative II requires fewer nodal element installations than the other architectures to provide the same performance, services and geographical coverage. Although the remaining components of operation and maintenance cost (discussed earlier) were not calculated in this analysis, it can be expected that consideration of additional O & M factors would increase the cost advantage of Architecture II over the other alternatives. This is so because the various types of nodal elements require similar installations, and hence the total cost of these additional factors tends to be primarily a function of the number of elements (thus favoring the alternative with the smallest element inventory). As discussed earlier in the appendix, no significant variation in the assumed 1988 element inventories is anticipated.

In view of these considerations, Architecture II is preferred from an O & M cost standpoint. However, considering the magnitude of error associated with some of the basic assumptions, the cost advantage is not significant enough to eliminate the other alternatives from consideration.

d. Total System Cost Comparison Summary. In order to obtain a meaningful overall ranking of the alternatives based on their cost performance, the relative weight of each cost category must be considered. Although the comparative cost analysis specifically avoided calculating costs common to all alternatives, sufficient information is available to permit first order estimates of the total system costs:

- Transmission Costs - the comparative analysis yielded an annual cost of about $6 million ($500K/mo) for CONUS. Inclusion of the architecture independent portion of access area costs ($C_{AA}(K)$), and extension of the analysis to overseas, produces a figure of approximately $20 million per year.

TABLE C-VIII. PROJECTED O&M PERSONNEL COST

ARCHITECTURE ALTERNATIVE	NODAL ELEMENT INVENTORY	PERSONNEL REQUIRED	ESTIMATED ANNUAL O&M PERSONNEL COST (1977 $K PER YEAR)
I	10 PSN	630	12,220
	6 CSF	372	7,278
	78 I-S/A AMPE	+ 6,864	+ 133,068
		7,866	152,566
II	10 PSN	630	12,220
	15 I-S/A AMPE (E)	1,470	28,425
	63 I-S/A AMPE	+ 5,544	+ 107,478
		7,644	148,123
III	10 PSN	630	12,220
	6 CSF	276	5,460
	12 I-S/A AMPE (E)	1,128	21,840
	66 I-S/A AMPE	+ 5,808	+ 112,596
		7,842	152,116

NOTES:

1. NODAL ELEMENT INVENTORIES ARE BASED ON TYPICAL 1988 NETWORK CONFIGURATIONS.
2. PERSONNEL REQUIREMENTS REPRESENT SITE TOTALS, ASSUMING FOUR SHIFTS.
3. AVERAGE YEARLY COSTS ARE BASED ON PERSONNEL RATES FOUND IN REFERENCE b.

AD-A071 671 BOOZ-ALLEN AND HAMILTON INC BETHESDA MD F/G 17/2
INTEGRATED AUTODIN SYSTEM (IAS). MID-TERM ARCHITECTURE DEFINITI--ETC(U)
FEB 79 A MESSINA, W LANDIS, J POULOS, R DEWEY DCA100-77-C-0057
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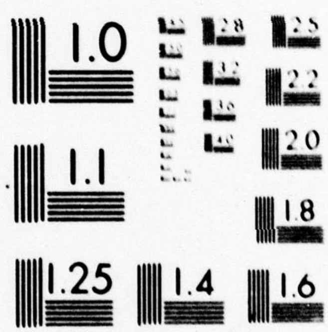

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

- Nodal Element Acquisition Costs - the comparative analysis showed an annual cost of approximately $40 million. The addition of costs common to the three alternatives (such as software development, installations, etc.) is expected to double this figure. Amortization over a 10-year economic life yields an estimated annual cost of $10 million.

- Operation and Maintenance Costs - the analysis of personnel costs was quite comprehensive, and led to an annual figure of about $150 million. Additional O & M costs utilities, facilities support, and spares, suggest a total annual cost of approximately $200 million.

In summary, the transmission cost will be essentially the same for each alternative (approximately $10 M per year). The system acquisition cost may be slightly higher for Alternative II than the other two alternatives ($10 M vice $9 M per year) and the O & M cost for Alternative II may be slightly lower ($195 M versus $200 M per year). As a result, Architecture II seems to offer a slight advantage over the other alternatives in terms of the total cost of ownership. However, the total cost impact of any architecture choice is probably less than 10 percent of the total annual cost of the IAS. Therefore, no alternative can be eliminated solely on the basis of cost.

3. COMPARISON OF MID-TERM ARCHITECTURE TO PROJECTED BASELINE

a. The Projected Baseline. In order to gain insight into the potential advantage to DCA of implementing any of the alternative mid-term IAS architectures, the comparative cost analysis was expanded to include comparison of Architecture II with the 1983 baseline architecture projected to a probable 1988 configuration (presented in Table C-I). The projected baseline architecture used in this analysis would incorporate only those changes and upgrades required to maintain current system capabilities. The projected baseline, when compared with the mid-term architecture, provides a clear indication of the impact that will result if little or no action is taken toward the evolution of the AUTODIN system. In addition, this comparison clearly emphasizes the potential cost savings of the mid-term architecture.

The projected 1983 baseline architecture is based on the following assumptions:

- ASCs retained in operation with minimum essential hardware/software subsystem replacement

- AMPEs retained in all current locations and replaced at the end of their useful service life with a "standardized" AMPE.

Based on current DoD policy, the projected baseline architecture includes provision for replacement of existing AMPEs with some form of standardized AMPE. However, because these equipments would not have the additional capability of the I-S/A AMPE used in the mid-term architecture, it is unrealistic to assume that consolidation could be achieved in the projected 1983 baseline architecture. Therefore, the number of AMPEs projected for the 1988 configuration was derived from current and planned AMPE requirements (see Appendix A).

The comparison between the Architecture II and the projected baseline centers on major cost elements, as before, but extends some categories to include common factors (such as PSN and AMPE costs). This helps provide a feel for the order of magnitude of the absolute costs.

b. Transmission Cost. The comparative analysis of transmission cost of subsection 2a. revealed very little cost sensitivity to the architectural configuration or the basic underlying assumptions. Furthermore, the projected baseline must provide the same geographical coverage, and meet the same performance requirements as the alternative mid-term architectures. Therefore, no significant difference in link configurations is anticipated. Any of the candidate mid-term architectures may yield, however, some cost savings, arising from the more effective use of traffic concentration and nodal processing.

c. Nodal Element Acquisition Cost. A comparison of projected network element acquisition cost for Architecture II versus the projected baseline was performed, using the same basic approach and assumptions outlined in subsection 2b. The results are summarized in Table C-IX. Only acquisitions unique to each architecture have been included (original AMPEs remaining in 1988 and PSNs are present in both alternatives). The cost of replacement AMPEs ("standardized") was estimated at 80% of the I-S/A AMPE cost, using the sizing approach described earlier in this appendix. As evidenced by the results, total estimated acquisition cost of the Architecture II is approximately $3.3 million greater than that of the projected baseline. However, when total useful service life of the elements is considered, the cost impact is relatively insignificant.

d. Operation and Maintenance Cost. The comparison of operation and maintenance cost for Architecture II versus the projected baseline followed the same procedure and assumptions used to evaluate the alternative architectures. The analysis focused, again, on personnel costs, and the comparative results are summarized in Table C-X. As

TABLE C-IX. NODAL ELEMENT ACQUISITION COST COMPARISON

	REQUIRED ACQUISITIONS	ESTIMATED COST PER ELEMENT	(1978 $) SYSTEM COST
MID-TERM ARCHITECTURE (II) (1988)	15 I-S/A AMPE (E)	$861K	$39.9M
	63 I-S/A AMPE	$428K	
PROJECTED BASELINE (1988)	107 AMPE (REPLACEMENT)	$342K	$36.6M

NOTES:

1. EACH ELEMENT HAS BEEN DEFINED IN TERMS OF HARDWARE COMPONENTS SELECTED FROM TYPICAL STATE-OF-THE-ART COMMUNICATIONS PROCESSING SYSTEMS.
2. COST ESTIMATES REPRESENT PROJECTED ACQUISITION COSTS FOR NETWORK ELEMENTS BASED ON COMMERCIAL HARDWARE SUITABLE TO A FIXED PLANT ENVIRONMENT, AND DO NOT INCLUDE THE COST OF SPARE PARTS, DOCUMENTATION, OR OTHER SUPPORT COSTS.
3. COST ESTIMATES DO NOT INCLUDE AMORTIZATION OF HARDWARE OR SOFTWARE DEVELOPMENT COSTS.
4. ELEMENT INVENTORIES ARE BASED ON TYPICAL 1988 NETWORK CONFIGURATIONS.
5. SUNK COSTS, INCLUDING PSNs, TERMINALS, ETC., HAVE BEEN EXCLUDED FROM THE COST COMPARISON.
6. THE AMPEs SHOWN IN THE PROJECTED BASELINE ELEMENT INVENTORY ARE STANDARDIZED AMPEs WHICH REPLACE CURRENT (NEAR-TERM) AMPEs DURING THE MID-TERM.
7. THE COST OF REPLACEMENT AMPEs WAS ESTIMATED AT 80% OF THE I-S/A AMPE COST.

TABLE C-X. O&M PERSONNEL COST COMPARISON

1983 BASELINE EXTRAPOLATED TO 1988			MID-TERM ARCHITECTURE (II)		
	TOTAL PERSONNEL	TOTAL COST ($K/YR)		TOTAL PERSONNEL	TOTAL COST ($K/YR)
• CONUS:			• CONUS:		
8 PSN	504	9,776	8 PSN	504	9,776
4 ASC	452	9,776	8 I-S/A AMPE (E)	704	15,100
104 AMPE	9,224	178,518	50 I-S/A AMPE	4,400	85,300
			22 AMPE (CURRENT)	2,000	40,300
	+ 10,180	+ 197,070		+ 7,776	+ 160,504
• OVERSEAS:			• OVERSEAS:		
2 PSN	126	2,444	2 PSN	126	2,444
7 ASC	791	15,358	7 I-S/A AMPE(E)	806	13,265
35 AMPE	3,125	60,465	13 I-S/A AMPE	1,144	22,178
			10 AMPE (CURRENT)	850	18,340
	+ 4,042	+ 78,267		+ 2,986	+ 56,227
• SAVINGS DUE TO COLOCATION OF PSN's WITH ASC's (4 IN CONUS, 2 OVERSEAS)	− 120	− 2,380	• MANNING REQUIREMENTS FOR 29 AMPES WHICH REVERT TO LOCAL TERMINAL/MESSAGE CENTER STATUS AS A RESULT OF CONSOLIDATION.	+ 870	+ 16,500
• TOTALS:	14,102	272,940	• TOTALS:	11,564	223,310
NET SAVINGS ACHIEVED BY MID-TERM ARCHITECTURE:				2,540	$ 49,570 · 10^3/YR

NOTES:

1. PERSONNEL LEVELS AND RATES ARE THOSE LISTED IN TABLE C-VI
2. COST CALCULATIONS ARE BASED ON TYPICAL 1988 NETWORK CONFIGURATIONS.
3. THE PROJECTED BASELINE INCLUDES CURRENT AMPES WHICH WILL BE IN SERVICE THROUGH 1988 AS WELL AS STANDARDIZED AMPES WHICH REPLACE CURRENT AMPES DURING THE MID-TERM.

evidenced by this table, Architecture II offers a potential net savings of over 2500 personnel with a resultant net cost savings of almost $50 million per year. It should be noted that the cost analysis takes into account the fact that many of the existing and planned AMPE sites, eliminated through consolidation, will revert to local terminal/message center operation. As a result, many of the O & M personnel formerly required at the AMPE sites will be retained for operation of the terminal/message centers (see Table C-VI). The magnitude of the potential savings indicated by this analysis demonstrates clear opportunity for significant reduction of total AUDODIN system operation and maintenance cost through implementation of any of the alternative mid-term IAS architectures.

REFERENCES

a. DCA, Integrated AUTODIN System Architecture, December 1977

b. DCAC 600-60-1, DCA Cost and Planning Factors Manual, 21 February 1978 Revision

APPENDIX D

DETAILED EVALUATION OF ALTERNATIVE MID-TERM IAS ARCHITECTURES

APPENDIX D
DETAILED EVALUATION OF ALTERNATIVE ARCHITECTURES FOR THE MID-TERM IAS

1. INTRODUCTION

In order to determine the preferred Mid-Term IAS Architecture, the three alternative architectures described in Section II of this report were evaluated with respect to their effect on system performance. Obviously, the actual performance of the Mid-Term IAS system cannot be accurately predicted solely on the basis of an architectural level definition, since detailed system performance requirements (based on future user applications and needs) cannot be specified until much later in the system definition and design cycle. Also, it must be remembered that each alternative architecture, by definition, is capable of meeting the anticipated future performance requirements of the Mid-Term IAS (to the extent that these requirements are known) within the limits of available technology. The thrust of this evaluation process, therefore, was to identify significant differences at the architectural level among alternatives in terms of the expected difficulty, complexity, or risk that would be encountered in providing a given level of performance. As a result, this evaluation concentrates on the differences among architectures and does not attempt to predict the absolute performance of any alternative.

a. Purpose. This appendix describes the evaluation criteria and analysis process used to evaluate alternative architectures for the Mid-Term IAS. In addition, this appendix presents the results of the evaluation process and describes the significant differences between alternatives identified in the evaluation process with respect to each evaluation criterion. Finally, this appendix summarizes the overall results of the evaluation process and provides the reasons for selection of Alternative II as the preferred Mid-Term Architecture.

b. Scope. This analysis addresses the three candidate architectures described in Section II of the body of this report. The evaluation process addresses four major evaluation criteria:

- Operational Effectiveness
- Flexibility
- Survivability/Availability/Supportability
- Transition.

This analysis is limited to an assessment of the relative desirability of each alternative architecture. No attempt is made to project or evaluate the probable system performance in quantitative terms.

2. EVALUATION CRITERIA

Within each of the four major evaluation criteria identified above, a number of subcriteria were identified as the first step in the analysis process. The major evaluation criteria and the subcriteria within each criterion are defined in the following paragraphs.

a. Evaluation Criterion 1: Operational Effectiveness. This criterion addresses the probable impact of architecture selection on the expected difficulty, complexity or risk of achieving the required level of functional and operational performance. The subcriteria identified within this evaluation criterion are defined in the following subparagraphs.

(1) Subcriterion 1: Speed of Service. This subcriterion refers to the probable response time or end-to-end delay performance possible in the final system for a given level of technical risk or cost.

(2) Subcriterion 2: User Motivated Interfaces. This subcriterion refers to the degree of design and operational complexity associated with user access to network services and user interaction with network service elements.

(3) Subcriterion 3: Transmission Efficiency. This subcriterion refers to the relative amount of overhead information that will be required for addressing, routing, flow control, error control, and system control.

(4) Subcriterion 4: System Motivated Functions. This subcriterion refers to the degree of design or implementation complexity that will be required to accomplish network control, message accountability, technical control, and traffic control in the final system.

(5) Subcriterion 5: Security. This subcriterion reflects the relative difficulty of meeting the Mid-Term IAS Security Objectives (see Appendix E).

(6) Subcriterion 6: Adaptability to Overseas Implementation. This subcriterion refers to the degree of difficulty and risk associated with the overseas implementation of network elements and services.

b. Evaluation Criterion 2: Flexibility. This criterion addresses the ability of a system that results from a given architecture to accommodate changes in day-to-day operation, and also to accommodate expansion and continued evolution throughout the mid-term timeframe. These two aspects of flexibility are referred to as adaptability and expandability. Adaptability refers to the ability of the system to accommodate changes in the demand for or utilization of its planned capabilities. Expandability refers to the ability of the system to accommodate additional requirements in the future. The subcriteria identified within this evaluation criterion are defined in the following subparagraphs.

(1) Subcriterion 1: Traffic Type Adaptability. This subcriterion refers to the relative impact on overall system performance of changes in user demand for planned traffic types.

(2) Subcriterion 2: External Interface Adaptability. This subcriterion refers to the impact of day-to-day changes in the volume of traffic passing between the IAS system and external systems.

(3) Subcriterion 3: Network Service Adaptability. This subcriterion refers to the ability of the system to tolerate changes in the user demand between ASC replacement functions and new network services.

(4) Subcriterion 4: Subscriber/Traffic Distribution Adaptability. This subcriterion refers to the ability of the system to accommodate day-to-day changes in the distribution of both subscribers and traffic types.

(5) Subcriterion 5: Subscriber Expandability. This subcriterion refers to the impact on the network of long-term changes in the number of terminations and the types of subscriber terminations supported by the network.

(6) Subcriterion 6: Protocol Expandability. This subcriterion refers to the relative impact of adding new user level, link level, and network level protocols to the system.

(7) Subcriterion 7: Service Expandability. This subcriterion refers to the relative impact of adding new network services to the network.

(8) Subcriterion 8: Control Function Expandability. This subcriterion refers to the ability of the system to accommodate changes in the numbers and types of control functions in the network.

(9) Subcriterion 9: Traffic Expandability. This subcriterion refers to the ability of the system to expand in terms of the volume of traffic handled by the network.

(10) Subcriterion 10: External Interface Expandability. This subcriterion refers to the ability of the system to accommodate new and additional external interfaces in the future.

c. Evaluation Criterion 3: Survivability/Availability/Supportability. This criterion considers the inherent abilility of an architecture to provide the required system performance in both normal and hostile operating environments. The subcriteria identified for this category are defined in the following subparagraphs.

(1) Subcriterion 1: Effect of Failures. This subcriterion refers to the expected loss of service and user access resulting from loss of a node or link in the system.

(2) Subcriterion 2: Failure Recovery. This subcriterion refers to the difficulty or complexity of the procedures required to recover from a failure or loss of a network node or link.

(3) Subcriterion 3: Failure Protection. This subcriterion reflects the degree to which an architecture permits system design alternatives that can be used to protect against failure or loss of a node or link.

(4) Subcriterion 4: Supportability. This subcriterion refers to the expected cost and difficulty of maintaining system performance under normal conditions (e.g., assuming no hostile actions) over the system's life cycle. Supportability is measured by the total number of elements to be maintained and the degree of commonality among elements.

d. Evaluation Criterion 4: Transition. This criterion addresses the difficulty of evolving from the current near-term architecture to the alternative mid-term architecture. This criterion also considers

the ability of a candidate architecture to support continued evolution into the far-term. The subcriteria identified within this category are defined in the following subparagraphs.

(1) Subcriterion 1: Development Risk. This subcriterion refers to the technical and management risk associated with developing the new nodal elements required to implement each architecture.

(2) Subcriterion 2: User Impact. This subcriterion refers to the probable impact on the current AUTODIN I and AUTODIN II user communities of implementing the alternative architecture.

(3) Subcriterion 3: Ease of Implementation. This subcriterion refers to the relative difficulty of implementing the new network elements and/or modifying the existing network elements in order to implement each architecture.

(4) Subcriterion 4: Potential for Evolution. This subcriterion refers to the ability of each architecture to support continued evolution beyond the mid-term. The potential for evolution thus reflects the extent to which the mid-term IAS can accommodate transition to a far-term IAS without constraining far-term alternatives.

3. EVALUATION METHODOLOGY

As indicated in Section 1, the level of detail inherent in the description of an architecture is not sufficient to support a predictive evaluation (i.e., an evaluation that predicts IAS performance). Thus the evaluation of alternative architectures is appropriately performed on a relative basis in which the architectures are compared to each other with respect to the evaluation criteria. In order to accomplish the relative evaluation, the architectures were ranked with respect to each evaluation subcriteria, and a Figure of Merit (FOM) was developed that aggregates this set of rankings into an overall ranking of the architectures.

The evaluation process is conveniently described as a two stage process. The first stage is the ranking of architectures with respect to each evaluation subcriteria. The second stage is the development of a FOM for each architectural alternative.

The first stage of the evaluation is accomplished by the following three steps:

- For each subcriterion, examine the alternative architectures and identify potential differences in system performance with respect to that subcriterion

- Based on the identified differences, rank the alternatives from the most desirable to the least desirable (allow ties in ranking if differences are not significant)

- Based on the ranking, assign "quality points" to each alternative on a scale for 1 to 5.

An important aspect of this process is that any two alternatives (or all three) can be ranked equally with respect to a given subcriterion. The principal advantage of this approach is that evaluating the difference in potential performance between alternatives is reduced to the binary decision of whether one architecture is "preferred" to another. The absolute performance of each alternative need not be evaluated in order to make this decision. Thus, the evaluation process is based upon a relative, qualitative assessment consistent with the degree of definition inherent in an architectural description and based upon an objective binary decision process. As a final step in this process, the qualitative assessments are translated into numerical quality point scores on a scale from 1 to 5. The definitions of these scores is presented in Table D-I. As indicated by the table, a numeric score is assigned to each alternative based on the preference ranking with respect to each subcriterion. In subsequent discussions the results of the evaluation process are expressed in terms of these quality point scores.

The second stage of the evaluation process is the aggregation of the rankings into an overall figure of merit (FOM) for each alternative architecture. The steps in this process are:

- The rankings are first aggregated with respect to each evaluation criterion as follows: For each evaluation criterion, calculate the average quality point score by summing the individual subcriterion quality point scores and dividing the sum by the total number of subcriteria

- Calculate overall FOM for each alternative by summing the average quality point scores for each evaluation criterion.

TABLE D-I. ASSIGNMENT OF QUALITY POINTS

Evaluation of Alternative (Preference Ranking Result)	Quality Point Score
Clearly more desirable than either of the other alternatives	5
More desirable than one of the other alternatives, but equally desirable to the remaining alternative	4
More desirable than one alternative and less desirable than the remaining alternative	3
No preference among alternatives	3
Less desirable than one of the other alternatives but equally desirable to the remaining alternatives	2
Clearly less desirable than either of the other alternatives	1

For the purpose of later discussions, it is useful to express this process mathematically as follows. If we let the FOM for the ith alternative be F_i, then:

$$F_i = \sum_{j=1}^{n} Q_{ij}$$

where Q_{ij} is the average quality point score for the ith alternative with respect to the jth evaluation criterion, and n = the number of evaluation criteria (in this case, n = 4).

Q_{ij} can be evaluated as:

$$Q_{ij} = \frac{1}{m} \sum_{k=1}^{m} Q_{ijk}$$

where Q_{ijk} is the individual quality point score for the ith alternative with respect to the kth subcriterion of criterion j, and m is the number of subcriteria within the ith evaluation criterion.

As discussed later in this appendix, the contribution of each criterion or subcriterion can be adjusted through the introduction of weighting. In this case the evaluation of F_i and Q_{ij} become:

$$F_i = \sum_{j=1}^{n} W_j \cdot Q_{ij}$$

$$Q_{ij} = \frac{1}{m} \sum_{k=1}^{m} W_{jk} \cdot Q_{ijk}$$

where W_j is the weighting factor for the jth evaluation criterion and W_{jk} is the weighting factor of the kth subcriterion of criterion j. The next section presents the results of the evaluation process.

4. EVALUATION RESULTS

This section presents the results of the evaluation process described in the preceding section for each of the four major evaluation criteria. The quality point scores as well as the significant factors which led to the architecture evaluations for each subcriteria are presented.

a. Evaluation Criterion 1: Operational Effectiveness.

(1) Subcriterion 1: Speed of Service. The principal factors in determining the eventual system performance in terms of speed of service are transmission delays, nodal element processing/queuing delays, and delays introduced by operating procedures, protocols, and control functions. These factors, in general, are determined by system design and implementation technology rather than by the architecture. The only architectural factor that impacts speed of service is the hierarchical structure of the system that results from the architecture. A measure of this architectural characteristic is the number of element-to-element links between a user and a service element or between a user and another user in a normal transaction. Therefore, in order to evaluate the qualitative difference between architectures for this subcriterion, the number of links required for each type of transaction anticipated in the Mid-Term IAS was calculated for each alternative architecture. Table D-II presents the results of this analysis. As indicated in the table, path lengths weree calculated for Architectures II and III assuming the I-S/A AMPE is singly connected as well as assuming the recommended configuration where the I-S/A AMPE is connected to both a PSN and an I-S/A AMPE(E). In all cases, the worst case backbone path was assumed to be two PSNs, and the best case backbone path was assumed to be one PSN. The evaluation of architecture alternatives was based upon the results of this analysis.

In general, the speed of service performance of a system will be specified in terms of a worst case maximum response time or end-to-end delay for each type of message or transaction. The design of the system, therefore, is frequently determined by the worst case condition. The cost and risk of meeting the performance requirements will also frequently be determined by the worst case design limits. Accordingly, this evaluation focussed on the differences between architectures in terms of the maximum path delays that can result in the system. As indicated in Table D-II, if dual connection of the I-S/A AMPE is assumed for Architectures II and III, the worst case path length for each architecture is the same for all traffic types except narrative message transfer. Since delivery time for narrative message traffic is not as critical as for interactive, query/response or teleconference traffic, this difference is not considered significant.

As indicated by Table D-II there is a potential difference between alternatives in terms of the best case delay possible for teleconference, gateway, message retrieval, and mailbox services. However, these best case differences occur in Alternatives II and III only for users directly connected to the I-S/A AMPE(E) that also provides the network service. Since most users will be connected either through an I-S/A AMPE or a PSN, only a small subset of the users will

TABLE D-II. SPEED OF SERVICE ANALYSIS

TRAFFIC TYPE	TRANSACTION PATH LENGTH IN NUMBER OF LINKS TRAVERSED (BEST CASE/WORST CASE)				
	ARCHITECTURE				
	I	II A*	II B**	III A*	III B**
. INTERACTIVE (USER TO USER)	2/5	2/7	2/5	2/7	2/5
. QUERY/RESPONSE (USER TO USER)	2/4	2/5	2/4	2/5	2/4
. NARRATIVE (USER TO USER)	2/8	2/9	2/9	2/9	2/9
. BULK (USER TO USER)	2/5	2/7	2/5	2/7	2/5
. FACSIMILE (USER TO USER)	2/5	2/7	2/5	2/7	2/5
. TELECONFERENCE (USER TO TELECONFERENCE CONTROL)	2/4	1/5	1/4	2/4	2/4
. GATEWAY (USER TO GATEWAY)	2/7	1/7	1/7	2/7	2/7
. MESSAGE RETRIEVAL (ELEMENT TO USER)	2/4	1/4	1/4	1/4	1/4
. MAILBOX (USER TO MAILBOX)	2/7	1/7	1/7	1/7	1/7

*A - I-S/A AMPEs Singly Connected to I-S/A AMPE(E) or PSN

**B - I-S/A AMPEs Dualy Connected to I-S/A AMPE(E) and PSN

experience the "best case" delay. Therefore, the difference is not considered sufficient to create a clear preference for one alternative.

The principal result of this analysis is evidence of the importance of dual connecting the I-S/A AMPE in Architectures II and III. As shown by Table D-II, if the I-S/A AMPE is singly connected to the I-S/A AMPE(E), the worst case path delay for Alternatives II and III will be much larger than for Alternative I. This is due to the user - I-S/A AMPE - I-S/A AMPE(E) - PSN - PSN - I-S/A AMPE(E) - I-S/A AMPE - user path that can occur in each of these architectures. However, if the I-S/A AMPE is connected to both a PSN and an I-S/A AMPE(E), the worst case path for Architectures II and III is reduced to a user - I-S/A AMPE - PSN - PSN - I-S/A AMPE - user path which is identical to Architecture I. As a result, the final Mid-Term IAS speed of service performance should not be greatly affected by the selection of any of the alternative architectures. Therefore, the three alternative architectures are ranked essentially equally for this subcriterion and accordingly the quality point scores are as follows:

- Architecture I - 3 points
- Architecture II - 3 points
- Architecture III - 3 points

(2) Subcriterion 2: User Motivated Interfaces. This subcriterion measures the degree of complexity of the decision processes that must be performed by IAS users. This complexity in turn is dependent on the following two numbers:

- The number of different service elements that need to be accessed by the user

- The number of different ways in which each service element can be accessed.

There are two main reasons why the complexity of the IAS user decision process reduces to these two numbers. First, once a user achieves access to a network service element, the complexity of the processing is a function of system design and therefore is not an architectural issue. Therefore, the analysis of this subcriteria (at the architectural level) is appropriately confined to analysis of the process of accessing service elements. Secondly, the virtual message protocol and other I-S/A AMPE features are identical in each architectural alternative. Therefore, the complexity of the accessing process is the same in each alternative. The complexity of the user decision process thus reduces to the number of choices that the IAS user has in accessing the network.

In Architecture I, there is only one type of service element. This element is the CSF. All traffic, regardless of type, must be routed directly to the nearest CSF for processing. Therefore, the accessing procedures and network protocols employed in Architecture I have the least complexity possible.

Architecture II, like Architecture I, has only one type of service element. This element is the I-S/A AMPE(E). However, in Architecture II, unlike Architecture I, the service element can be accessed two different ways:

- Direct access by locally connected subscribers
- Remote access through the network.

The existence of two access approaches to the I-S/A AMPE(E) appears to cause Architecture II to require more complex user processing than Architecture I. However, the actual increase in complexity need not be significant, because the additional processing steps implied by the two access approaches can be embodied in the design of the I-S/A AMPE(E) itself and thus can be separated from the user level equipment.

Architecture III has both the CSF and I-S/A AMPE(E). Network services are divided between these two service element types. Furthermore, at least some users (e.g., those directly connected to PSNs) will be required to make addressing and routing decisions based on the type of service required for each transaction. Consequently, Architecture III is less desirable than Architectures I and II with respect to this subcriterion. Accordingly the quality point scores are as follows:

- Architecture I - 4 points
- Architecture II - 4 points
- Architecture III - 1 point.

(3) Subcriterion 3: Transmission Efficiency. Transmission efficiency reflects the relative amount of overhead information required for addressing, routing, flow control, error control, and system control. Since the overhead required for addressing and routing is essentially a function of the number of subscribers and switching elements contained in the system and since these numbers are system design and implementation issues, no major differences were seen between the alternatives within these areas.

The overhead required to accomplish traffic control is considered essentially the same for each architecture. If dual connection of the I-S/A AMPEs is assumed, as indicated in the speed of service analysis, the average transmission paths will be essentially the same for each alternative. Therefore, the amount of overhead represented by error control procedures (resulting from end-to-end error rate differences) will be essentially the same for each alternative.

From the standpoint of system control implementation, the presence of the I-S/A AMPE(E) within the access area in Architectures II and III, is considered to be an advantage because it permits control functions at a lower level in the network than Architecture I. However, the dual connection of the I-S/A AMPE could offset this advantage in Architectures II and III by requiring more complex accounting and control functions. Taking all these factors into consideration, Architectures II and III are considered essentially equal in their probable performance with respect to this criterion. Architecture I is considered to be slightly less desirable. Therefore, the quality point scores for the alternatives as a result of this subcriterion are:

- Architecture I - 1 point
- Architecture II - 4 points
- Architecture III - 4 points.

(4) Subcriterion 4: System Motivated Functions. System motivated functions are those functions required to support system operation rather than to directly provide user services. Typical system motivated functions include network control for performance assessment and status monitoring, accountability, technical control, and traffic control. The principal differences between architectures with respect to this subcriterion result from differences in the degree of complexity required to design and/or implement the Mid-Term IAS system motivated functions for each alternative architecture. In general, the complexity of the system implementation in this area reflects the number of different types of service elements as well as the total number of elements required to implement the given architecture. Based on the constraints established in Section II of this report, the number of PSNs will be independent of the architecture selected. In addition, since the number of I-S/A AMPEs will be based upon the user distribution, the number of I-S/A AMPEs can be assumed to be equal for all three alternatives. However, since the I-S/A AMPE(E) replaces existing I-S/A AMPE sites in Architecture II, this alternative will require the smallest total number of elements for a given level of performance. If we assume that the number of CSFs in Architecture I and III will be based upon the number and distribution of users, then the total number of elements in both of these alternatives will be equivalent. In terms of the number

of different types of network elements, Architecture II has an advantage over the other alternatives, because of the high degree of commonality between the I-S/A AMPE(E) and the basic I-S/A AMPE. Architecture III on the other hand, with both a CSF and I-S/A AMPE(E), in addition to the required PSN and I-S/A AMPE, represents the largest number of different types of elements to be supported. As a result, the network control functions will be most complex in Architecture III, least complex in Architecture II, and somewhere between these two extremes for Architecture I. Another important consideration pertinent to this subcriterion is the difficulty of maintaining accountability in the Mid-Term IAS network. In this regard, Architectures I and II have an advantage over Architecture III, in that fewer network service elements would be encountered in a typical narrative/record transaction flow through the network. Additional considerations with respect to this subcriterion are technical control and traffic control. Architecture I was found to have a slight advantage over the other two alternatives in the area of technical control since the technical control for the I-S/A AMPE(E) contained in Architectures II and III would be somewhat more complex than that required for the CSF contained in Architecture I. No significant difference was identified among the alternatives in the area of traffic control complexity. Considering all of the above factors, and the relative strengths and weaknesses of each alternative, Alternatives I and II were judged to be approximately equal in their desirability with respect to this subcriterion. Architecture III on the other hand was judged to be somewhat less desirable than either of the other two alternatives. Consistent with this evaluation, the quality point scores for this subcriterion are:

- Architecture I - 4 points
- Architecture II - 4 points
- Architecture III - 1 point.

(5) <u>Subcriterion 5: Security</u>. The security functions of the Mid-Term IAS will be provided by a security subsystem, which is integrated into the various network elements. The allocation of the security subsystem functions and the operation of the security subsystem will vary depending upon the architecture selected. In order to evaluate the alternative architectures with respect to this subcriterion, a likely implementation of the security subsystem for each alternative was defined and evaluated. The results of this evaluation are presented in detail in a separate classified appendix (Appendix E). In general, the security analysis reveals that an effective security subsystem can be implemented in each of the alternative architectures. As a result, the three alternatives are ranked equally with respect to this subcriterion and the quality point assignment is as follows:

- Architecture I - 3 points
- Architecture II - 3 points
- Architecture III - 3 points.

(6) <u>Subcriterion 6: Adaptability to Overseas Implementation</u>. The evaluation of the alternative architectures with respect to this subcriterion concentrated on differences among the alternatives with respect to their ability to support mobile terminals and mobile network elements, the CONUS/Overseas trunking requirements associated with each alternative, and the risk associated with overseas deployment of the network service elements used in each architecture.

In comparing the ability of the architectures to utilize mobile or transportable elements overseas, the required network element sizes and the impact of movement of elements on users must be considered. The size of the network elements is in turn determined by the functional allocation within the architecture and the throughput requirement of the network elements that results from the architecture hierarchy. As indicated in the network element acquisition cost analysis described in Appendix C, the I-S/A AMPE(E) used in Architecture II is the single largest element used in any architecture based on both functional allocation and communications interface requirements. This element will therefore be the most difficult to implement as a mobile/transportable element. In addition, since the I-S/A AMPE(E) used in Architecture II also terminates a large number of subscribers, the impact of moving this element after initial deployment is significant. In contrast, the CSF used in Architecture I is almost as large or larger than the I-S/A AMPE(E) used in Architecture II from the standpoint of functional capability. However, because the CSF in Architecture I interfaces only to a PSN rather than to many subscribers, and is accessed via the network rather than directly, it is much more amenable to redeployment. Finally, the CSF and I-S/A AMPE(E) used in Architecture III represent the smallest network element size because the functional requirements are approximately evenly divided between these two elements. However, the potential impact on users connected to the I-S/A AMPE(E) in this case is the same as for Architecture II. Based on the offsetting advantages of Architecture I and Architecture III, they are judged to be equally desirable with respect to the feasibility of mobile network elements. Architecture II is less desirable than the other two alternatives in this regard.

In terms of the ability to support mobile terminals, Architecture I is rated slightly more desirable than the other two architectures. This results from the concentration of all network services within the CSF which is accessed via the network by all users and is therefore relatively insensitive to the location and distribution of users at any time. The other two architectures are considered to be approximately equal in this regard.

The risk of overseas deployment of network elements considers the effect of overseas deployment on network vulnerability. As a result of the analysis, no significant differences among architectures were identified in this area. Similarly, no significant difference was found in the requirement for CONUS/Overseas trunking between the three architectures. As a result of the analysis, it was determined that the CONUS/Overseas trunking requirements depend primarily upon the connection alternatives within architectures and whether the service elements are located overseas along with the PSNs.

When all of the above factors are taken into account, Architecture I was judged to be the most desirable from the standpoint of its ability to adapt to an overseas environment. Architecture III was judged to be the next most desirable architecture for overseas implementation, and Architecture II was judged to be less desirable than either of the other alternatives. Accordingly the quality point assignments with respect to this subcriterion are:

- Architecture I - 5 points
- Architecture II - 1 point
- Architecture III - 3 points.

(7) Summary of Evaluation for Operational Effectiveness. The results of the evaluation process for all subcriteria within this evaluation criterion are summarized in Table D-III. As indicated by this table, Architecture I and Architecture II are essentially equal with respect to their overall operational effectiveness. Both architectures are clearly preferred to Architecture III in this regard. It is interesting to note that in all respects, except for transmission efficiency and adaptability to overseas implementation, Architectures I and II are judged to be equally desirable. It is also interesting to note that Architecture III is judged to be more desirable than each of the other alternatives in only one of the six subcriteria.

b. Evaluation Criterion 2: Flexibility. This criterion is especially important because the mid-term architecture must be flexible in order to accommodate changes in requirements and to allow continued evolution throughout the mid-term. Of major concern is the impact of possible inaccuracies in the current estimates of the number of subscribers, traffic volume, and utilization of network services. As indicated in Section 2, architecture evaluation for flexibility focuses on differences between alternatives in terms of both adaptability and expandability. The results of the evaluation process for each subcriterion within this category are presented in the following subparagraphs.

TABLE D-III. EVALUATION FOR OPERATIONAL EFFECTIVENESS

Subcriterion	Quality Point Score Arch I	Arch II	Arch III
1. Speed of Service*	3	3	3
2. User Motivated Interfaces	4	4	1
3. Transmission Efficiency	1	4	4
4. System Motivated Functions	4	4	1
5. Security	3	3	3
6. Adaptability to Overseas	5	1	3
Total Score	20	19	15
Average Score (Q_{ij})	3.3	3.2	2.5

*Assumes dual connection of I-S/A AMPE

(1) Subcriterion 1: Traffic Type Adaptability. No significant differences were identified between alternative architectures with respect to this subcriterion. As a result, the quality point scores for this subcriterion are:

- Architecture I - 3 points
- Architecture II - 3 points
- Architecture III - 3 points.

(2) Subcriterion 2: External Interface Adaptability. The volume of traffic directed outside the network as opposed to within the network will impact the nodal traffic flows and the loading on the network elements involved in the gateway function. Since in each alternative architecture the gateway function is assigned to a single network service element designated as the gateway to a particular external network, no significant differences between alternatives were identified. As a result, quality point scores for this subcriterion are:

- Architecture I - 3 points
- Architecture II - 3 points
- Architecture III - 3 points.

(3) Subcriterion 3: Network Service Adaptability. The evaluation of alternatives with respect to this subcriterion concentrated on the utilization of ASC replacement services versus new services. Differences between architectures in this regard reflect the differences in allocation of these services within each architecture. For example, Architecture I provides all network services from a single centralized service element (i.e., the CSF). If the CSF is designed to permit a reasonable degree of load sharing, it should be relatively insensitive to variations in the utilization of particular services. In addition, since individual subscribers are not allocated to a designated CSF (homed), there is an additional opportunity for load sharing among the CSF facilities within the network. Since all CSFs are accessed via the backbone network, this network load sharing should not significantly degrade the response time performance of the network.

Architecture II also allocates all services to a single network element (i.e., the I-S/A AMPE(E)). If properly designed, it, too, offers the advantage of nodal load sharing. However, since some subscribers are connected directly to the I-S/A AMPE(E) and some are connected via an I-S/A AMPE that is dual connected to a PSN and an I-S/A AMPE(E), network level load sharing, while possible, is somewhat more complex in this alternative. For example, traffic entering the network via the I-S/A AMPE that requires network services will normally be

routed directly to the connected I-S/A AMPE(E). If that element is unavailable, however, traffic from the I-S/A AMPE can be routed via the connected PSN to another I-S/A AMPE(E).

Architecture III offers approximately the same degree of network level load sharing as Architecture II because of the dual connected I-S/A AMPE and I-S/A AMPE(E) connected subscribers. However, because the network services are split between two network service elements (CSF and I-S/A AMPE(E)), this architecture does not offer the same degree of node level load sharing. As a result of these factors, Architecture I is considered to be the most adaptable to changes in demand for network services followed by Architecture II and Architecture III, in that order. Accordingly, the quality point scores with respect to this subcriterion are:

- Architecture I - 5 points
- Architecture II - 3 points
- Architecture III - 1 point.

(4) Subcriterion 4: Subscriber/Traffic Distribution Adaptability. This subcriterion measures the sensitivity of the system to changes in the day-to-day distribution of traffic. For example, traffic patterns in the network could change drastically during a crisis situation. Typical perturbations include sudden shifts in the ratio of local versus remote traffic or significant increases in the amount of traffic in a particualr region. Differences between alternatives with respect to this subcriterion reflect differences in the funtional allocation among service elements as well as differences in the user access to these services.

Architecture I is considered to be the least sensitive to changes in subscriber and traffic distribution because the CSF is accessed via the backbone by all subscribers. In fact, it is likely in Architecture I that a particular subscriber would be unaware of which CSF was providing the service functions for any given transaction. Assuming the PSN switching nodes and trunks were properly sized to handle the worst case traffic flows, sudden shifts in traffic distribution would have little or no effect on overall system performance in Architecture I. The same general comments apply to Architecture III but only with respect to the new network services provided by its centralized CSF. The ASC replacement functions allocated to the I-S/A AMPE(E) in Architecture III and all network service functions in Architecture II would be somewhat more sensitive to traffic distribution. Further, it is expected that during the mid-term timeframe, perturbations are more likely to occur in the narrative/record traffic (i.e., the ASC replacement functions) than in the new network service traffic. Therefore, the difference between Architectures II and III is not considered significant. Finally, it must be remembered that the virtual message protocol (VMP) and the dual connection of the I-S/A AMPE permit most single

address narrative/record traffic to be exchanged between I-S/A AMPE connected subscribers without requiring processing by the higher level service elements in any architecture. Therefore, the basic performance of all three architectures with respect to this subcriterion will be significantly better than the current AUTODIN system.

Taking all of the above factors into account, Architecture I is considered to be the most desirable alternative with respect to this subcriterion. Architectures II and III each are considered to offer essentially the same level of system performance. Accordingly, the quality point scores are:

- Architecture I - 5 points
- Architecture II - 2 points
- Architecture III - 2 points.

(5) Subcriterion 5: Subscriber Expandability. The ability of a system to expand both in the number and types of subscribers is a function of the subscriber termination configurations permitted by an architecture. Since each alternative provides essentially the same subscriber termination alternatives (i.e., PSN connected or I-S/A AMPE connected), there are no significant differences between the alternatives with respect to this subcriterion. As a result, the quality point scores are:

- Architecture I - 3 points
- Architecture II - 3 points
- Architecture III - 3 points.

(6) Subcriterion 6: Protocol Expandability. The architectures were compared in terms of their ability to accommodate new user level, network level, and link level protocols in order to meet evolving user requirements. The introduction of new user level protocols and link level protocols will impact subscriber terminal equipments and, potentially, the I-S/A AMPE and PSN subscriber interfaces. Since these elements are common to all three alternatives, no significant differences between the architectures were identified with respect to link level or user level protocol expandability. Similarly, new network level protocols involving service element-to-service element transfers should have an equal impact on each architecture. A significant difference between alternatives was identified in terms of the impact of introducing new user-to-service protocols.

In Architecture II the same family of network elements (i.e., I-S/A AMPE and I-S/A AMPE(E)) provides both network services and user termination. Therefore, changes in the user-to-service element protocols can be implemented within these elements. In Architectures I and III, however, the central service facility does not terminate subscribers directly. Therefore, changes in the user-to-service element protocols could impact both the I-S/A AMPE and the CSF. During the mid-term timeframe, it is expected that new user-to-service element protocols will most likely be introduced as a result of the new network services. Since new network services are allocated to the CSF in both Architecture I and Architecture III, no significant difference is expected between these two alternatives. As a result, Architecture II is considered to be the most desirable alternative with respect to this subcriterion. Architectures I and III are both considered to be slightly less desirable. The quality point scores are:

- Architecture I - 2 points
- Architecture II - 5 points
- Architecture III - 2 points.

(7) Subcriterion 7: Service Expandability. This subcriterion refers to the relative impact of adding new network services to the Mid-Term IAS. Since each alternative permits the same degree of implementation options, differences between architectures with respect to adding new services are concentrated on the degree of flexibility provided to the system designer in allocating the new services to network elements. As a result, Architecture III was judged to be the most flexible in its ability to add new network services because it offers the option of implementing functions in one of two network service elements (i.e., the CSF or the I-S/A AMPE(E)). No significant differences were identified between Architecture I and Architecture II. Therefore, the quality point scores with respect to this subcriterion are:

- Architecture I - 2 points
- Architecture II - 2 points
- Architecture III - 5 points.

(8) Subcriterion 8: Control Function Expandability. This subcriterion measures the ability of the system to accommodate changes in the numbers and types of control functions used in the network. Differences among alternatives with respect to this subcriterion result from differences in the number of elements and the number of different types of elements contained in each architecture. These numbers, in turn, affect the complexity of the control functions. As discussed previously with regard to system motivated functions, Architecture II has the fewest numbers and types of network elements.

As a result, the implementation of new control functions at a future date is considered to have less impact on Architecture II than on the other architectures. Accordingly, the quality point scores with respect to this subcriterion are:

- Architecture I - 2 points
- Architecture II - 5 points
- Architecture III - 2 points.

(9) Subcriterion 9: Traffic Expandability. There are two primary methods available to increase the traffic handling capacity of the network—increase the number of service elements or increase the size of the existing service elements. No significant differences were identified between the architectures in terms of their ability to add additional service elements as required. In terms of the ability to expand the size of existing service elements, there is a potential difference. As discussed previously with regard to the mobility of service elements used overseas, the I-S/A AMPE(E) used in Architecture II has the highest communications throughput of any service element used in the architectures. Therefore, the upper limit of memory size and/or processing speed in the I-S/A AMPE(E) may be reached at a lower traffic volume in Architecture II than in the other architectures. This would require the introduction of additional service elements and the redistribution of subscribers at an earlier stage of growth. Therefore Architecture II is somewhat less desirable than the other architectures with respect to traffic expandability. Alternatively, the service elements in Architecture III have the smallest communications throughput of the service elements used in the architectures. Consequently, Architecture III can be expected to offer the highest degree of flexibility in terms of service element expansion versus introduction of new service elements. Accordingly, the quality point scores with respect to this subcriterion are:

- Architecture I - 3 points
- Architecture II - 1 point
- Architecture III - 5 points.

(10) Subcriterion 10: External Interface Expandability. The interface between the IAS network and external systems may be either user oriented, as in the case of allied/tactical interfaces, or network oriented, as in the case of interfaces to external packet networks. The optimum allocation of gateway functions for user oriented external systems interfaces is to a user termination element such as the I-S/A AMPE(E). The optimum allocation for a network oriented external interface is to a centralized network element such as the CSF. Since Architecture III contains both the I-S/A AMPE(E) and the CSF, it permits

the optimum expandability with regard to external interfaces. Since it is not clear at this time whether future expansion of external interfaces will more likely involve user oriented or network oriented systems, Architectues I and II are considered equally acceptable. Consequently, the quality point scores with respect to this subcriterion are:

- Architecture I - 2 points
- Architecture II - 2 points
- Architecture III - 5 points.

(11) Summary of Evaluation For Flexibility. The results of the evaluation process for all subcriteria within this evaluation criterion are summarized in Table D-IV. As indicated by this table, Architecture I is the least sensitive to day-to-day changes in the network operation because of its highly centralized structure. Architectures II and III, on the other hand, are more easily expanded in the future to accommodate evolving requirements. As a result, each architecture provides specific advantages with respect to flexibility and no one architecture is clearly preferred over the others overall.

c. Evaluation Criterion 3: Survivability/Availability/Supportability. Survivability is a major factor in the selection of a Mid-Term IAS architecture. Of almost equal concern is the availability of the system under normal conditions. In general, the factors that affect survivability also affect availability. Therefore, the evaluation of alternative architectures concentrated on three principal subcriteria: the effect of failures; the ability of the system to recover from failures; and the degree of failure protection inherent in the architecture. Supportability is also a major factor in the selection of a Mid-Term IAS architecture. One of the principal objectives of the Mid-Term IAS is to reduce the operation and maintenance costs associated with the AUTODIN system. The three factors of survivability, availability, and supportability are considered together as one evaluation criterion because factors that enhance survivability/availability sometimes adversely affect supportability. For example, distribution of functions among a large number of elements can tend to make a system more survivable. However, the resultant redundancy and physical distribution of hardware and software can also significantly increase the cost of maintaining and operating such a system. The results of the evaluation process with respect to each of the four subcriteria are presented in the following subparagraphs.

(1) Subcriterion 1: Effect of Failures. The effect on the total system of failures in individual elements will, in large measure, depend upon the degree of redundancy among service elements and communications facilities provided in the final system design. As a

TABLE D-IV. EVALUATION FOR FLEXIBILITY

	Subcriterion	Quality Point Score Arch I	Arch II	Arch III
1.	Traffic Type Adaptability	3	3	3
2.	External Interface Adaptability	3	3	3
3.	Network Service Adaptability	5	3	1
4.	Subscriber/Traffic Distribution Adaptability	5	2	2
5.	Subscriber Expandability	3	3	3
6.	Protocol Expandability	2	5	2
7.	Service Expandability	2	2	5
8.	Control Function Expandability	2	5	2
9.	Traffic Expandability	3	1	5
10.	External Interface Expandability	2	2	5
	Total Score	30	29	31
	Average Score (Q_{ij})	3.0	2.9	3.1

result, this evaluation concentrated on the inherent differences between architectures in terms of the concentration of functional capabilities and subscriber access within particular service elements that could result in "choke points" in the final system design and, hence, adversely affect survivability and availability. As a result of this analysis, Architecture II was identified as having such a potential choke point in the form of the I-S/A AMPE(E). As noted in previous discussions, the I-S/A AMPE(E) in Architecture II has a high communications traffic throughput compared to the service elements used in the other architectures. In addition, the I-S/A AMPE(E) in Architecture II concentrates both network service functions and a significant amount of the subscriber termination functions within a single element. Therefore, the I-S/A AMPE(E) in Architecture II represents a potential choke point in a stress environment. It should be noted, however, that even the loss of an I-S/A AMPE(E) in Architecture II will not have a catastrophic effect on the network operation. Since the I-S/A AMPEs which may be connected to the I-S/A AMPE(E) will be dual connected to a PSN, and since the services provided by the I-S/A AMPE(E) can also be provided by other I-S/A AMPE(E) nodes in the network, only those subscribers singly connected to the I-S/A AMPE(E) itself will experience a loss of service. Remaining subscribers to the network will experience only a degradation in performance.

As a result of the analysis, it was determined that loss of a CSF or I-S/A AMPE(E) in Architecture III or the loss of a CSF in Architecture I would have relatively equal effect on overall network operation. As a result, the quality point scores assigned for this subcriterion are as follows:

- Architecture I - 4 points
- Architecture II - 1 point
- Architecture III - 4 points.

(2) Subcriterion 2: Failure Recovery. The user level and system level procedures and functions required to recover from the loss of a link or node in each architecture were analyzed. In general, the procedures required to recover from such a loss depend upon the specific network services involved as well as the source and destination locations and the subscriber type. Consequently, no significant differences in failure recovery capability were identified among the alternatives. However, an important result of this analysis was the determination that all three alternative architectures will provide significant improvement over the Near-Term IAS with respect to their ability to recover from the loss of a node or link. For example, since subscriber terminal equipments and I-S/A AMPE equipments are not dependent upon a designated (homing) service element, the ability to recover from loss of the nearest service element is inherent in the routing and traffic distribution capability of the network. Therefore, no special procedures are required

to recover from the loss of any single service element. In addition, the use of the virtual message protocol (VMP) in the I-S/A AMPE to send most narrative/record messages provides a significant backup to the more complex multiple address and message processing functions provided by the higher level service elements. That is, if a CSF or an I-S/A AMPE(E) is lost, a subscriber connected to an I-S/A AMPE could still send multiple address messages, one at a time, using the VMP without assistance from a higher level service element. Finally, in the event a destination subscriber is inoperative or destroyed, the source subscriber can simply readdress the message either manually or automatically via the I-S/A AMPE and forward the message to a contingency destination. When these features are used singly or in combination, the result is an almost continuous graceful degradation from complete network capability to minimum network capability. Since the same features are available in each of the three alternative architectures, the quality point scores with respect to this subcriterion are:

- Architecture I - 3 points
- Architecture II - 3 points
- Architecture III - 3 points.

(3) Subcriterion 3: Failure Protection. The degree of failure protection provided by a given architecture is a function of the number of connection alternatives available between subscribers and service elements and the degree to which redundancy can be added to the network after initial implementation. Significant differences identified with respect to these two factors are discussed below.

Both Architectures II and III provide considerable flexibility in terms of the number of ways subscribers can be multiply connected to the network. In addition to the preferred configuration where an I-S/A AMPE is dual connected to both a PSN and an I-S/A AMPE(E) in both architectures, the I-S/A AMPE(E) will be dual connected to two different PSNs in most cases. Individual subscribers in these architectures may also be dual connected to two network elements of the same type depending upon the availability of adequate communications facilities. As a result, Architectures II and III offer the possibility of a more richly connected access area and, hence, greater protection against the loss of any single communications link or node than is available with Architecture I. In terms of the ability to increase redundancy after initial implementation, Architectures II and III again enjoy an advantage over Architecture I. Since any I-S/A AMPE can be upgraded to provide I-S/A AMPE(E) capability through simple addition of hardware/software modules, a high degree of redundancy is possible in Architectures II and III. Further, the redundancy of the network can be easily increased in incremental stages following initial implementation.

When all these factors are taken into account, Architectures II and III are preferred to Architecture I with respect to failure protection capabilities. Accordingly, the quality point scores with respect to this subcriterion are:

- Architecture I - 1 point
- Architecture II - 4 points
- Architecture III - 4 points.

(4) Subcriterion 4: Supportability. The supportability of the system based on architecture is a function of the number of elements required to implement a given level of system performance and the degree of commonality among elements within the architecture. As discussed previously, Architecture II, with a single network element based on the already defined I-S/A AMPE family, will require the lowest total number of elements to implement a given network capability. This factor, along with the high degree of commonality between the I-S/A AMPE(E) and the I-S/A AMPE, makes a system design based upon Architecture II the most supportable. Alternatively, Architecture III with its CSF and I-S/A AMPE(E) requires the largest number of network elements to implement a given network capability. In addition, the presence of two distinct families of equipment would increase the logistics and maintenance costs associated with a system based on Architecture III. Architecture I with a CSF and I-S/A AMPE would require more elements than Architecture II but fewer than Architecture III to implement the same network capabilities. It would, however, suffer from the maintenance and logistics difficulty associated with two separate families of equipment. As a result, Architecture II is considered to be the most desirable architecture from the standpoint of supportability followed by Architecture I and III, respectively. Accordingly, the quality point scores with respect to this subcriteria are:

- Architecture I - 3 points
- Architecture II - 5 points
- Architecture III - 1 point.

(5) Summary of Evaluation for Survivability/Availability/Supportability. The results of the evaluation process for all subcriteria within this evaluation criterion are summarized in Table D-V. As indicated previously, there is a clear tradeoff between survivability and maintainability. This is evidenced clearly with respect to Architecture II. The consolidation of all network service functions in a single network element, the I-S/A AMPE(E), based upon the existing I-S/A AMPE family of equipments, results in Architecture II having the lowest ranking with respect to effect of failures and the highest ranking with respect to supportability. Architecture III, on the other hand, with

TABLE D-V. EVALUATION FOR SURVIVABILITY/AVAILABILITY/SUPPORTABILITY

Subcriterion	Arch I	Arch II	Arch III
1. Effect of Failures	4	1	4
2. Failure Recovery	3	3	3
3. Failure Protection	1	4	4
4. Supportability	3	5	1
Total Score	11	13	12
Average Score (Q_{ij})	2.8	3.3	3.0

network service functions distributed across a larger number of elements tends to eliminate potential choke points or concentrations of service and user access while introducing significant logistics and maintenance difficulties. Because of the lower level of connectivity in the access region, Architecture I does not represent a good compromise between these two extermes. In attempting to resolve this tradeoff, significant weight must be given to the supportability consideration. As evidenced in the earlier discussions, each of the alternative architectures provides a significant improvement in terms of survivability over the near-term IAS. In addition, many network features common to all three alternatives provide graceful degradation and tend to minimize the potential differences in this area. Supportability, however, remains a driving concern for the mid-term. Since any mid-term architecture will represent a significant implementation cost, it is important that considerable attention be paid to operation and maintenance costs in order to optimize the life cycle cost of ownership for the IAS to the DoD. With this in mind, the quantitative advantage of Architecture II over the other alternatives in this evaluation category takes on increased importance in the overall selection of a Mid-Term IAS Architecture.

d. Evaluation Criterion 4: Transition. This evaluation criterion deals with the relative ease (or difficulty) of evolving from the Near-Term IAS to a specific mid-term architecture and beyond. Accordingly, subscriteria were defined to be: the degree of risk involved in the development of necessary network elements; the impact of the transition on Near-Term IAS users in terms of continuity of service and increased/modified operational procedures; the ease of implementation of the necessary network elements; and, finally, the potential for evolution to a far-term architecture. Results of the analysis with respect to each of these subcriteria are discussed below.

(1) Subcriterion 1: Development Risk. Because the state-of-the-art of available technology was considered as a constraint in the definition of each of the alternative architectures, and because the general development approach for the Mid-Term IAS network elements has been defined by DCEC, differences in the risk of successfully developing the necessary hardware and software implementation of IAS network elements will result from differences in the number of different development programs that must be managed, funded, and controlled in order to implement each architecture. Evaluation with respect to this subcriterion, therefore, concentrated on evaluation of the probability of success of the required hardware and software development program(s). Recognizing that the packet switched nodes (PSN) and subscriber terminal equipments are common developments to all three alternatives, Architecture I requires the development of the I-S/A AMPE and the CSF.

Architecture II requires the development of the I-S/A AMPE family of equipments including the I-S/A AMPE(E). Architecture III requires the development of the I-S/A AMPE family and the CSF. Since both the enhanced and basic versions of the IS/A AMPE family will be developed under a single program, and since the probability of success of this single development program is considered greater than the combined probability of success of two separate developments, Architecture II is expected to involve the least development risk. Because of the high degree of commonality within the I-S/A AMPE family, the difference in development risk between the two programs required for Architecture III is not considered significant. Accordingly, the assignment of quality points with respect to this subcriterion are:

- Architecture I - 2 points
- Architecture II - 5 points
- Architecture III - 2 points.

(2) Subcriterion 2: User Impact. No significant differences were identified between the architecture alternatives with respect to the probable impact on current users of the transition from the Near-Term IAS to the Mid-Term IAS. As described in Section IV of the body of this report, the transition from AMPE to I-S/A AMPE and from ASC to I-S/A AMPE(E) or CSF should not result in significant loss of continuity of service or disruption to existing user operating procedures. Therefore, the quality point scores with respect to this subcriterion are:

- Architecture I - 3 points
- Architecture II - 3 points
- Architecture III - 3 points.

(3) Subcriterion 3: Ease of Implementation. The probable complexity of implementing the mid-term architecture with respect to each alternative is a function of the number of network service elements that must be implemented and/or modified. In this context it should be remembered that the current transition planning assumes that I-S/A AMPE nodes will be implemented as a first priority. If Architecture II is selected as the preferred mid-term architecture, completion of the transition process will require only the enhancement of the previously installed I-S/A AMPE nodes. Architecture I, on the other hand, will require introduction of a totally new network service element - the CSF. Architecture III implementation will require introduction of a CSF and the enhancement of existing I-S/A AMPEs in order to create the necessary I-S/A AMPE(E) nodes. Additional modifications to subscriber terminal equipments, operating procedures, remaining ASCs, AMPEs, and PSNs will be required in all three architectures. As a result, Architecture II is

considered to be the best of the three alternatives in terms of implementation of the mid-term architecture, followed by Architecture I and Architecture III, respectively. Consequently, the quality point scores with respect to this subcriterion are:

- Architecture I - 3 points
- Architecture II - 5 points
- Architecture III - 1 point.

(4) Subcriterion 4: Potential for Evolution. The three alternative architectures were evaluated in terms of their potential to evolve towards two general classes of future IAS architectures—a satellite backbone architecture and an integrated voice and data architecture. The principal differences among architectures identified as a result of this analysis result from the allocation of network service functions to the access area versus the backbone. Specifically, Architecture I was considered somewhat restrictive to evolution to the two potential classes of far-term architecture because of the role of the CSF and its limitations as a backbone element. For example, retention of the CSF as the primary service element in a satellite backbone architecture could lead to multiple satellite hops between the source subscriber, the CSF, and the destination subscriber. Similarly, the implementation of an integrated voice and data network is likely to entail additional levels of switching within the access area, and consequently increase the distance between the subscriber and the backbone CSF service element. In general, therefore, both the satellite backbone and the integrated voice and data network architectures tend to favor architectures with services provided in the access area, closer to the users. As a result, Architectures II and III provide the best opportunity for continued evolution from the mid-term to the far-term. Accordingly, the quality point scores with respect to this subcriterion are:

- Architecture I - 1 point
- Architecture II - 4 points
- Architecture III - 4 points.

(5) Summary of Evaluation for Transition. Results of the evaluation process with respect to all four subcriteria within this evaluation category are presented in Table D-VI. As indicated in this table, Architecture II is preferred over the other two alternatives in three of the four evaluation subcriteria. The consolidation of all network functions in a single network element that can be derived from an existing R&D program allows the implementation of Alternative II in the mid-term with minimum development risk and implementation cost and complexity. In addition, the location of all network functions in the access area, close to the subscribers, facilitates the eventual implementation of both satellite backbone and integrated voice and data architectures at a future date.

TABLE D-VI. EVALUATION FOR TRANSITION

	Quality Point Score		
	Arch I	Arch II	Arch III
1. Development Risk	2	5	2
2. User Impact	3	3	3
3. Ease of Implementation	3	5	1
4. Potential for Evolution	1	4	4
Total Score	9	17	10
Average Score (Q_{ij})	2.3	4.3	2.5

e. Overall Evaluation. As indicated in Section III, the evaluation methodology consists of two distinct stages. The first stage, qualitative evaluation and the assignment of quality scores, was described in the preceding paragraphs. The second stage of the process, calculation of an overall figure of merit (FOM) for each alternative architecture, can now be accomplished. As indicated in Section III, the overall figure of merit (F_i) is calculated by summing the average quality point score derived for each evaluation criterion (Q_{ij}). The appropriate values of Q_{ij} and F_i, calculated from the evaluation process, are summarized in Table D-VII. As indicated by this table, Architecture II receives the highest overall figure of merit and is hence preferred over the other two alternatives. As indicated by this table, Alternative II is clearly preferred in the areas of survivability/availability/supportability and transition. In addition, Architecture II is evaluated to be almost as desirable as the better of the two remaining alternatives in the areas of operational effectiveness and flexibility. As a result, it is unlikely that further analysis of the alternatives would reverse these first order evaluation results.

As discussed in Section II, one of the principal reasons for calculating the overall figure of merit is to permit the application of weighting factors to the evaluation criteria. In order to determine the impact of weighting on the evaluation results, a set of candidate evaluation criteria weights were defined based on inputs from DCA. These weighting factors are:

- Operational effectiveness - 1.5
- Flexibility - 2.0
- Survivability/availability/supportability - 3.0
- Transition 3.5.

These weighting factors were applied to the quality point scores derived from Table D-VII. The weighted figure of merit scores that result from this process are:

- Architecture I - 27.4
- Architecture II - 35.6
- Architecture III - 27.7

As expected, the application of weighting factors does not change the results of the evaluation process. In fact, because of the small numerical difference between quality point scores of Architecture II and the other architectures in the two evaluation criteria for which Architecture II is not clearly preferred, no reasonable weighting of the evaluation criteria would change the principal evaluation results.

TABLE D-VII. OVERALL FIGURE OF MERIT (FOM) CALCULATION

Evaluation Criterion	Quality Point Score (Q_{ij}) Arch I	Arch II	Arch III
1. Operational Effectiveness	3.3	3.2	2.5
2. Flexibility	3.0	2.9	3.1
3. Survivability/Availability/ Supportability	2.8	3.3	3.0
4. Transition	2.3	4.3	2.5
Total FOM (F_i) =	11.4	13.7	11.1

5. RECOMMENDATION

Based on an analysis of technical factors, alternative Architecture II is recommended as the preferred Mid-Term IAS architecture. Based on its slightly higher rating than Architecture I in three of the four evaluation criteria, Architecture III is recommended as the first alternate.